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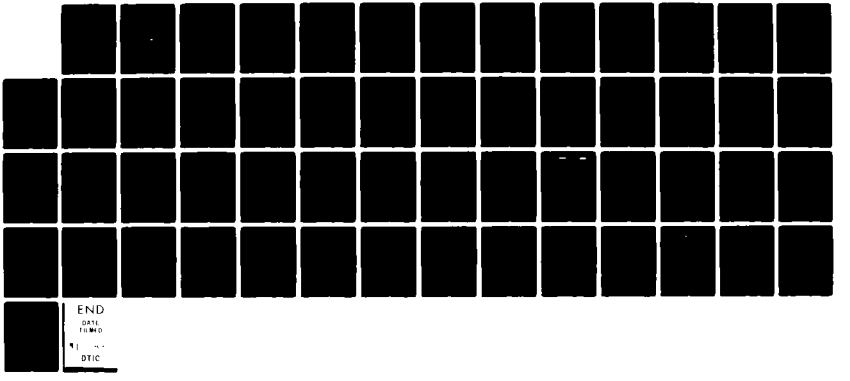

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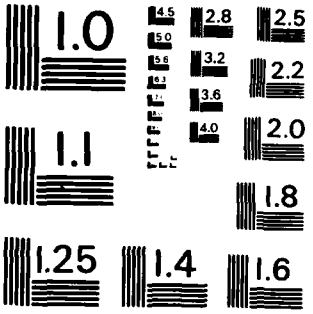

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European Scientific Notes (ESN) is a monthly publication with brief articles on recent developments in European scientific research. The publication is not intended to be part of the scientific literature. The value of ESN articles to Americans is to call attention to current developments in European science and technology and to the institutions and people responsible for these efforts. ESN authors are primarily ONRL staff members. Occasionally articles are prepared by or in cooperation with staff members of the USAF European Office of →

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EUROPEAN SCIENTIFIC NOTES
OFFICE OF NAVAL RESEARCH
LONDON

Edited by F.A. Richards
L.E. Shaffer

Vol 37, No. 9 30 September 1983

CHEMISTRY

Researchers at the Technical Univ. of Braunschweig have pioneered the use of polymer-bound biocatalysts. The preparation of immobilized cells and their use in biotechnical processes is described.

COMPUTER SCIENCES

The robotics research work at Genoa covers a wide number of subjects including a language for robotic manipulators, pattern analysis, a study of artificial vision, anthropomorphic robots, and trajectory formation and handwriting.

A West German group has developed a consensus language, which is designed to consolidate existing hardware description languages into a standard language.

ELECTRONICS

Thompson-Brandt, France's largest electronics company, leads the western world in III-V semiconductor R&D. They employ nearly 100 professionals in III-V research, 50 more in GaAs development and production, with 30 others to be added soon. Only Japanese companies are larger.

Although rapid thermal processing of semiconductor materials is already in production and appears to be critical in processing submicron devices, various aspects of the technology still are not well understood.

MATERIAL SCIENCES

This is the sixth in a series of articles reporting research on fiber composite materials in the UK. Research at the Atomic Energy Research Establishment and Imperial College is highlighted this month.

The Corporate Research Center at Brown Boveri is doing research on the strength and fracture mechanics properties of turbine blade materials. The Swiss Federal Institute of Technology (ETH-Zurich) is becoming a center for determining the effect of metallurgical variables on fracture mechanics parameters.

MATHEMATICS

The European Center for Medium-Range Weather Forecasts is exploiting its increased computer power to provide reliable weather forecasts for 5 to 6 days.

OCEAN SCIENCES

A NATO Advanced Institute dealt with the effects of ocean phenomena on chemical processes. Specialized working groups examined topics such as air-sea gas exchanges, particle distributions, and solutes.

North Sea oil and gas developments have significantly changed land use along the Scottish coast. However, the work apparently has caused little damage in the area.

OPERATIONS RESEARCH

Operations researchers from European countries tend to identify themselves as belonging to a group facing "European" problems. Compared with their US counterparts, they seem to be more concerned with philosophy, ethics, and the special problems of developing countries.

PHYSICS

Preliminary results of a new gas-puff plasma radiator experiment at Imperial College, London, are presented. The x-ray source will be used to study photo-pumping of x-ray lasers.

The Univ. of Manchester Institute of Science and Technology is examining the static electrification of aircraft moving through ice storms. Use of modern insulating components such as fiber composites increases the threat of static-charge-induced breakdowns.

SPACE SCIENCE

STATISTICS

NEWS & NOTES

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CHEMISTRY

POLYMER-BOUND BIOCATALYSTS

The use of isolated enzymes as effective and stable catalysts is well known. Recently, catalysis using whole microbial cells immobilized in a polymeric carrier has been shown to be highly effective. Such cells can be useful for long periods and have a number of other advantages.

Prof. Joachim Klein and his colleagues at the Institute of Chemical Technology, Technical Univ. of Braunschweig, Federal Republic of Germany, have pioneered and developed the technique with considerable success. The microbiological aspects are carried out in close cooperation with Prof. F. Wagner in the Department of Biochemistry and Biotechnology. Klein has systematically used various aspects of modern polymer chemistry to develop immobilization procedures. The polymeric network has to be built up in the presence of the cells under suitable physiological conditions so that they have the highest possible enzyme activity and lifetime.

The resulting immobilized cells are then studied experimentally to characterize them quantitatively as biocatalysts for technological use. Among the requirements are adequate pressure stability and flow-through, with little pressure drop and resistance to abrasion when stirred in a reactor. The effective diffusion coefficient in the matrix and its porosity are also important characteristics. Scanning electron microscopy has yielded valuable information about the cell-matrix systems. The reactivity of immobilized cells has been systematically compared with free cells in a number of reactions: the oxidative degradation of phenol with *Candida tropicalis* cells, the splitting of penicillin G and V, the synthesis of L-tryptophan and of a number of organic acids, and various fermentation procedures.

Preparation of the Immobilized Cells

Klein has developed many useful techniques that have been reviewed recently (Klein and Vorlop, 1983). The actual physical entrapment of the cells in a crosslinked porous matrix appears to be the best general approach. The network formation must be made under mild pH and temperature conditions in an aqueous environment. After formation, it must be chemically stable and capable of controlled size and porosity, preferably as beads. Clearly, the catalyst beads must be mechanically stable under various conditions--for example, in stirred tank, fluidized bed, and packed bed reactors. Two general methods of preparing immobilized cells have evolved. With both, high concentrations of cells, up to 70% on a wet weight basis, can be incorporated.

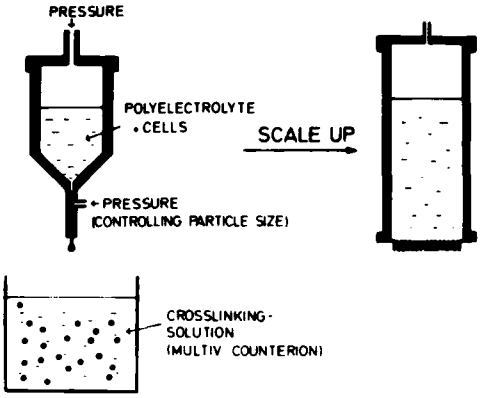

Figure 1. The ionotropic gelation of polyelectrolytes.

1. The so-called ionotropic gelation of polyelectrolytes. Polyanions such as the alginates, carboxymethyl cellulose, or maleic acid-styrene copolymers are mixed with the cells and crosslinked by the addition of multivalent cations. Alternatively, polycations--such as chitosan mixed with the cells--can be crosslinked by adding multivalent anions, such as polyphosphates. By forcing the crosslinked cell-polyelectrolyte mixtures through a nozzle into a bath of the crosslinking solution, particles of various sizes can be obtained. The process is shown in Figure 1.

2. The polycondensation of epoxy resins. A partially condensed aqueous solution of an epoxy resin and a multifunctional amine as the crosslinking agent is prepared. The cells are mixed in a separate vessel with an aqueous polyanion, such as an alginate. The two solutions are then united and injected into a polycation (such as calcium chloride solution), crosslinked and dried, and the alginate removed. This leaves the cells entrapped in porous epoxy beads. The process is shown in Figure 2.

The epoxy method can introduce toxicity problems due to the amine component; this can be minimized, however, by choosing suitable conditions (for example, see Klein and Kressdorf, 1982). Other methods of immobilizing whole cells also have been used, For

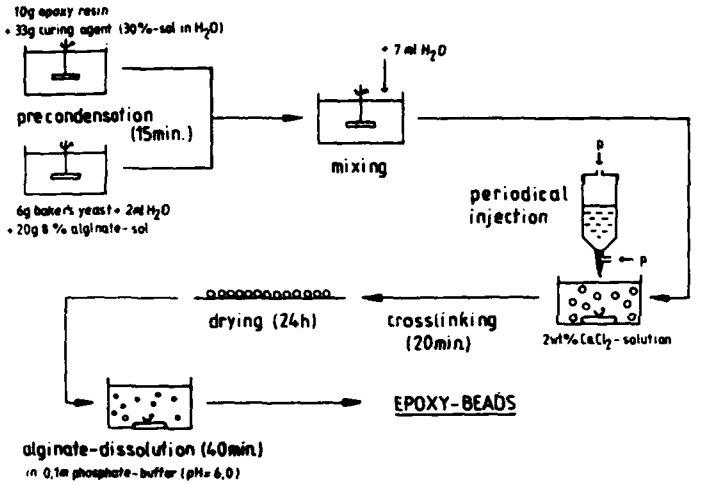

Figure 2. Cell entrapment in epoxy beads (from Klein and Vorlop [1983], 381, as reprinted from Ref. 14, *Science and Technology Letters*, copyright 1982).

example, various water-soluble polymers, including the polyurethanes terminated with isocyanates, have been crosslinked with water (See Klein and Manecke, 1982).

Immobilized Cells for Biotechnical Processes

A number of systems have been studied in detail. In an earlier paper (Klein and Wagner, 1980), the use of immobilized *F. coli* cells for the production of 6-amino penicillanic acid (6 APA) from penicillin G and V was described. The epoxy bead method was the most effective. The half lives were 40 days, compared with 1 day for the free suspended cells. The epoxy beads also had high abrasion resistance. The use of water-crosslinked aqueous polyurethane foams as the entrapment medium has also been studied (Klein and Kluge, 1981). In addition, the oxidative degradation of phenol, important for ecological reasons, was studied using whole cells of *Candida tropicalis* as a model system. Covalently crosslinked water soluble polymers, such as polyacrylamide, were used for the polymer entrapment.

Klein and Manecke (1982) have studied several other reactions, including the use of immobilized *Arthrobacter simplex* cells for the steroid transformation of cortisol to prednisolone. Polyvinyl alcohol and polyethyleneimine, covalently crosslinked by various reactions, were used as the entrapment polymers. The former was many times more effective. Other systems were also evaluated, including the steady-state production of ethyl alcohol from glucose using whole yeast cells in epoxy-based matrices. Klein and Vorlop (1983) discuss other studies and the methods used to evaluate the reaction parameters, including the diffusional transport behavior and catalyst optimization.

This article has outlined only the biotechnology work in Klein's large institute. Other groups are working on heterogenous acid catalysis, water soluble polymers for tertiary oil recovery, polymers as additives for lubricating oils, heterogenous gas reactions, and a number of organic geochemical problems. Fundamental polymer work includes extensive studies of inverse gas chromatography and its use for characterizing polymers and the structure and properties of polymer solutions.

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V.T. Stannett

COMPUTER SCIENCES

ROBOTICS AT THE UNIV. OF GENOA

Research at the Univ. of Genoa in robotics and artificial intelligence ranges from design of a language for robotic manipulators to screen interpretation, pattern analysis, study of artificial vision, anthropomorphic robots, and trajectory formation and hand writing.

Despite the variety of interests, the work in each field is of high professional quality. This article briefly summarizes most of the individual projects.

A Language for Robotic Manipulators

The work at Genoa deals with the description of motor tasks for a visual-motor-cognitive robot. Attention is given to abstraction, expressive levels, portability, the possibility of making "motor knowledge" grow, geometric reasoning, and interaction with the environment. To meet the general requirements, a research language called LENNY has been introduced.

The work is part of a larger project to develop methodologies and to study problems at different levels in the field of anthropomorphic robotics. The framework of the study is shown in Figure 1.

The scheme gives on one side the working environment, composed of the external (real) objects and the mechanical parts and sensors of the robot. On the other side is shown the internal representations of the world, in particular: (1) a "cognitive world model," which can be considered a representation of the actual external environment and plays the role of short-term memory; and (2) a "cognitive data base," which contains all the knowledge the system has about the real world. Its role is that of a long-term memory. The real world and the internal representation interact with each other by means of visual and motor channels.

The work at Genoa is restricted to the motor side, but the abstraction that is pursued is potentially compatible with a vision system, at least after the early levels of computation. The outputs of the motor channel are the activator commands to be sent to the mechanical device, and the inputs are device actions as planned by the cognitive component.

Tasks performed inside the motor channel are divided into three levels, characterized by the different nature of the processes involved:

- Flow level, in which data-driven computations are performed on large amounts of data.
- Process level, in which concurrent computations take place.

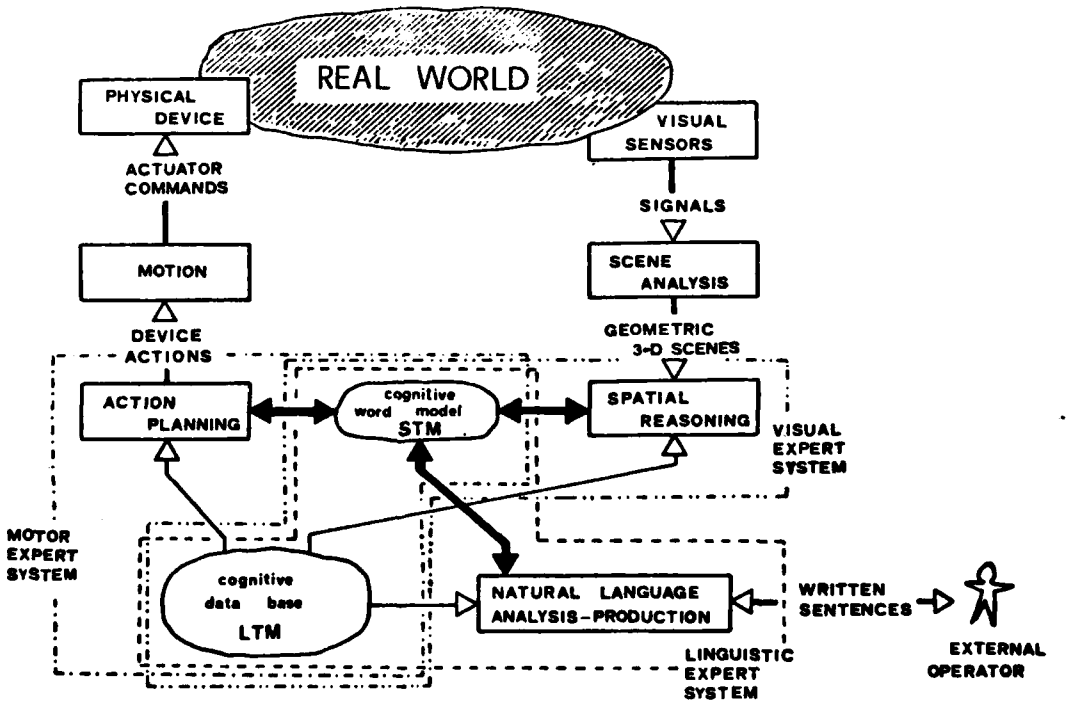

Figure 1. Study framework.

- Competence level, in which logical tasks are involved.

The objective of the work is to provide a sufficiently powerful expression of the complex chains of actions, which can save the competence level from large on-line jobs and can fit well with the human abstract capability to understand and represent processes.

LENNY is a compromise between the whole conceptual architecture and a set of constraints: implementation tools, efficiency, and the need for an early subset to verify design lines.

LENNY drives an emulated anthropomorphic manipulator and is oriented to kinematic descriptions of trajectories, so it lacks primitives for dynamic control. At the same time, the terminal device is modeled as a simple stick with no grasping capability. Nevertheless, LENNY contains the concepts of functionality, context dependency, abstraction, asynchronism, incrementality, "soft" default choices, and redundancy.

Top-Down Approach to Scene Interpretation

This work deals with the representation and manipulation of knowledge about physical objects, their positions in a given environment, and actions involving their use. The main goal is to determine how the inferential activities required to understand a statement are affected by the knowledge about the physical characteristics of the environment of the statement itself, what specific reasoning rules are used to handle physical objects, and how such reasoning capabilities can be implemented in an anthropomorphic robot.

The study deals mainly with representation of physical objects and the formalization of spatial relationships, trying to point out how linguistic and visual information can be related. Moreover, inferential mechanisms are developed to allow the generation of a scene description beginning with information about some objects, possibly connected through spatial relationships.

Every object modeling technique must deal with several issues. Objects must be described at several levels of detail. In some cases, only a rough definition of dimensions is sufficient, while in other cases a more sophisticated knowledge of structure is required. The calculation of movable object parts must be properly described; the movements of different objects usually follow different rules. Characteristic features of objects must be pointed out. The recognition of a feature allows the generation of hypotheses about the presence of an object. Typical relationships between objects must be described.

Such issues are taken into account through organization of knowledge based on a set of thoughts and an associated body of descriptions. A thought is a frame-like structure within which new data are interpreted in terms of concepts acquired through previous experience. Four types of thought determine sets of operations applicable to thoughts:

1. A descriptive thought defines a physical object in a conceptual dependency-like formalism.
2. A prototype thought defines the structural part of a physical object.
3. A joint thought defines the element of connection among physical objects with the goal of building more complex objects or scenes.
4. A spatial thought defines spatial relationships like "on," "near," or "on the left of" objects.

The work is still in progress, but the long-term goal is to determine how specific knowledge and assumptions about the physical environment of a statement can be used in general purpose reasoning. Most work in the near future will be on the development of a more complete set of inferencing rules to handle dynamic scenes in which, for example, the trajectories of a movable object are significant in the reconstruction of the environment.

Spatio-Temporal Pattern Analysis of Visually Evoked Potentials in Humans

The aim of this work is to demonstrate the efficiency of a bidimensional analysis of brain electrical activity in increasing the spatial resolution of scalp-recorded visually evoked potentials (VEP). The analysis is carried on either by visual inspection or by automatic feature extraction from the bidimensional data. The system used is a derivation of the BEAM system proposed by Duffy et al. (1979), and is based on the topography of brain electrical activity. The maximum resolution achievable by the technique was tested by searching the minimum distance (in millimeters of cortex) that could be resolved either by visual inspection or by measurement of bidimensional features. Visual stimuli were used because of the available knowledge about the visual pathway and particularly about the relationship between degrees of visual angle and millimeters of cortex (cortical magnification factor). Such knowledge permits design of a set of

stimuli normalized with respect to the activated cortical area and to their relative distance. VEP from 12 electrodes were recorded from eight normal subjects and for 12 different stimuli positioned over the lower visual field. The stimuli activate about 1 cm^2 of visual cortex, and their projections were separated from 7 to 10 mm. The results show that the resolution achievable in the localization of the electrical activity worked by the stimuli is less than 1 cm^2. The figure depends on the experimental paradigm. Nonetheless, the result proves that if the data are processed correctly and enough information is collected, the minimum resolution of the recording of the electrical activity from the scalp is quite high.

A Model of the Early Stages of the Human Visual System

The early stages of the visual system were modeled--with particular reference to the regions of the visual field outside the fovea and to the class of retinal and lateral geniculate nucleus cells that are most active in the processing of pattern information (x-cell). The main neuroanatomical and neurophysiological properties taken into account are the linear increase of the receptive field's diameter with eccentricity, the constancy of the overlap factor, and the topological transformation operated upon the retinal image by the retina-cortical connection. The filtering between the retina and the visual cortex was analyzed, and some simulations were presented. It was shown that such filtering is of a bandpass, space-variant type, with center frequencies that decrease from the center (fovea) toward the periphery of the visual field. The processing is "form invariant" under linear scaling of the input. Moreover, considering the properties of the retina-cortical connection, it was shown that the "cortical images" undergo simple shifts whenever the retinal images are scaled or rotated.

Anthropomorphic Features in Artificial Vision

Robots being designed to operate in man-oriented environments should incorporate some anthropomorphic features. The project considered: (1) the design of a retina-like structure in order to compromise between a large visual field and acceptable resolution, and (2) the use of linguistic techniques to capture embedded structures and organizations from the rough data acquired by the peripheral vision system. Researchers attempted to verify the extent to which the two factors influence each other.

The need for giving "visual intelligence" to an anthropomorphic robot requires combining two fields of study that, in neuroscience, have been investigated separately: (1) retinic transduction and early processing of visual information, and (2) cognitive mechanisms of visual perception.

A "linguistic" approach, as in dealing with a verbal language, can be hypothesized for other types of complex behavior, such as skilled motor performance or human-like visual perception. The image of a scene is extremely redundant, and the information content is reduced in the selective process of feature extraction. On the other hand, the information in the image of physical objects is insufficient because it is generated by three-dimensional and two-dimensional perspective projection over the retina. Projection destroys information and requires, for partial recovery of three-dimensional information, combining the available two-dimensional data with hypotheses concerning the constraints given by the three-dimensional world. Mixing data and hypotheses is typically a linguistic matter involving symbol manipulation and semantic processing.

Models of "retinic vision" and "cognitive vision" were examined during the project. The model of retinal visual transduction and early visual processing emphasizes geometrical and topological characteristics, and singles out an attractive compromise between spatial resolution, spatial range, and memory size. The model of cognitive visual processing interprets the scene as a hierarchy of features (edges, lines, and surfaces).

The adoption of a retina-like structure to acquire pictorial data and the use of linguistic techniques have the common goal of reducing visual information by working at different hierarchical levels of scene analysis. Therefore, the two approaches should be used with other methodologies in order to mimic human vision. From a technological viewpoint, there is no need to find a single solution for the vision problem. A wise and coordinated use of several different theories and techniques could allow the design of efficient artificial vision devices.

Form-Invariant Topological Mapping Strategy

The project on a form-invariant topological mapping strategy for two-dimensional shape recognition has two objectives:

1. To generate a bidimensional description of some objects representing the system "world," and

2. To analyze unknown scenes in order to assign each object in a scene a degree of membership to an object of the "world." The procedure is distinctive because of topological transformation that converts an object into a different "entity," whose shape is invariant under rotation and linear scaling. In addition, the topological transformation approximates that performed by the human visual system when passing from the retinic image to the cortical image, on which the first stages of the cognitive analysis are performed. The system has industrial applications: for example, it could be suitable for a hardware reali- zation using a sensor whose elements are disposed according to a specific geometry.

Anthropomorphic Robotics

Two aspects of anthropomorphic robotics are being examined:

1. Representing mechanical complexity. A study of the fundamental principles upon which manipulation dexterity is based combines robotic and neurophysiological concepts. A preliminary step is to try to understand the complexity of manipulation dynamics. Though complexity is indicated by the massive number of elements of kinematic and dynamic equations, the fundamental simplicity of the underlying mechanical laws suggests that researchers might look for a computational structure. Accordingly, a working model was proposed that organizes the computational load into a structure composed of a small number of computational units and lends itself to parallel computation.

2. Analysis of manipulator dynamics and output motor impedance. The relationship between a set of disturbing forces and the resulting variation in arm configuration is being studied. The functional significance of such force-displacement characteristics is being investigated. The research shows how several aspects of different manipulation (such as holding against gravity, inserting, fast moving, and throwing) can be described naturally in terms of appropriate modulation of the impedance characteristics of the manipulator. Impedance modulation can be considered an integral part of motor control.

The Inverse Kinematic Problem for Anthropomorphic Manipulator Arms

The inverse problem for manipulator arms consists of computing the time course of the joint free variables, which correspond to a desired time course of the position or orientation of the hand in space. Complicated trigonometric equations must be solved; furthermore, for anthropomorphic manipulator arms, the problem is undetermined, requiring the solution of an associated optimization task. The proposed approach is recursive, partly analytical, and partly numerical. From a geometrical model of the arm, based on rotation matrices and vectors, two algorithms are derived. The first is used to compute a sequence of arm configurations (the output variables) from a given sequence of hand positions or orientations (the input variables). The second is used to adjust the updated configurations according to a quadratic optimization criterion.

Trajectory Formation and Handwriting

This project proposes a computational model for different aspects of trajectory formation, from point-to-point movements to handwriting. The proposed model is based on a mechanism of composition of basic curve elements (strokes) that separates the spatial and temporal aspects of trajectory formation. The model also suggests a method for storing and describing arm movements as a list of stroke descriptions. Experimental trajectories were digitized and analyzed with respect to several types of movements: (1) point-to-point trajectories, (2) closed trajectories, (3) trajectories with inflection points, (4) spiral-like trajectories, and (5) handwritten trajectories. Velocity and curvature profiles were computed for the trajectories, and the model was fitted to the data.

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J.F. Blackburn

THE CONLAN PROJECT

Conlan (Consensus Language) is a formal language construction mechanism that can be used to describe data processing hardware and firmware at different levels of abstraction. Conlan has been developed at Technische Hochschule (Darmstadt, Federal Republic of Germany) by an international working group chaired by Prof. R. Piloty.

The project was started in 1973 to consolidate existing hardware description languages into a standard language.

A decade ago, there were several dozen hardware description languages, and new ones were being proposed and published every year. However, they were not being readily accepted by industry. They were not being used to document the design of digital systems, nor to support tools for certification, synthesis, and performance evaluation. In many cases, the block and circuit diagrams at the integrated circuit package or gate level were the only true and complete documentation of a system. Other aspects of system design and behavior were informally or incompletely described.

There are several reasons for the poor acceptance of existing hardware description languages: (1) none of the languages alone is of sufficient scope to portray all aspects of a system and cover all phases of the design process; (2) languages of different scope are syntactically and semantically related; (3) few of the languages are formally defined; (4) only a few languages are implemented; (5) descriptions are represented by character strings rather than diagrams; and (6) there is no comprehensive hardware and firmware design methodology telling how to use hardware design languages effectively.

The primary objectives of the Conlan working group are:

1. To provide a common formal syntactic base for all aspects of hardware and firmware description.
2. To provide a means to derive from this common base user languages that have a limited scope adjusted to a particular class of design tasks, are easy to learn and simple to use, and have a well-defined semantic relation.
3. To support computer aided design tools for documentation, certification, design space exploration, and synthesis.
4. To avoid imposing a single, rigid style of hardware description on makers of design tools.

To meet the above objectives, the language has to be able to represent hardware at several levels of abstraction, including flip-flops, gate networks, and algorithms. The Conlan approach is a family of related languages with consistent syntax and semantics for similar object types and operations. The family has to be extensible, but in order to be consistent, the extensibility has to be controlled. Conlan supports a self-defining, extensible family of languages tied together by a common core syntax and a common semantic definition system. Each new language definition segment is based on an existing one, its reference language, to improve consistency and increase language definition efficiency. Description definition segments are provided so that member languages can be used to write descriptions of hardware, firmware, or software modules. New languages, which can be derived from existing ones, may be used later as reference languages for further languages.

To start the Conlan family, a root language called Base Conlan (BCL) was prepared by Piloty's group. Base Conlan is defined by a set of object types and operations, the syntax, and an associated mode of computation. The term "toolmaker" is used for those who prepare new members of the Conlan family and supporting software. "Users" employ the new languages and supporting software to record hardware design efforts. Toolmakers may use the types and operations introduced by a Conlan segment to derive new languages or describe hardware. In the system, toolmaker entities have identifiers and can only be referenced in a language definition statement. However, user entities can be referenced in a language definition statement or in a description segment. Entities to be used only for derivation do not have to be known by the user or implemented by the toolmaker.

Conlan text consists of properly nested blocks. Those defining an entity, either a language item or hardware module, are called segments. Those referring to or invoking an instance of a segment are called statements. Segments begin with a key word followed by an identifier and terminate with the keyword END, which may be followed by the segment identifier. Most statements begin with a keyword and terminate with END, which may be followed by the opening key word.

Lists of operation invocations in Conlan do not imply a sequence of execution, and there are no sequencing operations, like "go to," provided as primitives. All invocations of operations are potentially executed concurrently, at least within the scope of one block. Conditional invocations of operations (IF statements), however, permit time selection of operation execution by specifying conditions on the system state under which an operation is supposed to be executed.

Conlan provides operation definition segments, which specify a new operation for later invocation in a behavior description, and description definition statements, which specify hardware module types. The description

segments describe the structure of hardware by nested instantiation of predefined module types. A module type may be described either by submodules or operation invocations. Thus, Conlan allows its user the choice of structural description, behavioral description, or both.

The language definition segment defines a new member of the Conlan family, while the description definition segment defines a hardware or firmware system. For both toolmakers and users, the outermost segment in both cases must be prefaced with a reference language statement (REFLAN). A new language is said to be derived from its reference language. All members of the Conlan family are derived directly or indirectly from BCL. Primitive Set Conlan (PSCL), a low level but powerful language, formally defines BCL. BCL then provides more elaborate objects that are expected to be useful for hardware description throughout the Conlan family. Other members of the family are expected to provide additional hardware and firmware items as objects. All objects are members of at least one universal set, named "univ @," provided by PSCL.

A Conlan object TYPE consists of a set of objects (its domain) and operations on the members of that set. The operations are defined explicitly in terms of operations already defined. The TYPE segment provides a way to specify the set membership and define operations of the defined type. A TYPE segment may be parameterized, providing for a family of types obtained by binding the formal parameters to actual parameters.

TYPE segments within a Conlan or description segment may be written in terms of non-PRIVATE types of the reference language. TYPE segments can be written in terms of previously written TYPE segments. Subtypes can be derived from existing types using a SUBTYPE segment, with the domain being a subset of the domain of the parent type.

Toolmakers sometimes must group into a class type with a common property. A class called "any @," which contains all types, is provided by PSCL.

New operations are defined with FUNCTION and ACTIVITY segments. The FUNCTION segment defines an operation that selects and returns an element of a specified type. The ACTIVITY segment defines an operation that does not return objects. ACTIVITY segment identifiers may not appear in expressions. FUNCTION and ACTIVITY segments may be prefixed with keyword INTERPRETER @ to indicate that the defined operations are to be invoked by the environment of the Conlan member of which the operations are a part.

Conlan uses the international standard ISO 646 character set and code. Although the semantics of most symbols of that set have been determined by Piloty's group, toolmakers may assign semantics to a few remaining symbols and to compound symbols. Conlan deals with the following categories of entities: objects, operations, types, classes, descriptions and instances of descriptions, and languages.

In the Conlan language, segments marked PRIVATE are neither visible nor accessible to future toolmakers and users. Identifiers and keywords that terminate with the symbol @ also are not visible to users. The CARRY statement reveals segments to be propagated from a reference language to a new language. EXTERNAL statements can be used to avoid repetitive writing of the same Conlan text. A predicate is any expression that produces a Boolean result. FORALL @, FORSOME @. and FORONE @ statements test the domain of a type against an embedded predicate and evaluate to true (1) or false (0) as the keywords suggest.

The THE @ statement selects the one element of the domain for which an embedded predicate is true. The ALL statement selects all elements for which an embedded predicate is true. As this statement may be needed by users, it is not restricted by a terminal @ symbol.

The IF and CASE statements selectively invoke one of a list of operations based on the value of a predicate or predicates. Both permit an ELSE part.

The OVER statement provides a short way of writing a collection of operation invocations that differ only in the value of an index.

The evaluation sequence between several invoked FUNCTION segments is expressed by an operator hierarchy and the use of parentheses. However, procedural descriptions of hardware are not possible until a Conlan member language is written that provides suitable control structures.

The DECLARE statement provides a means of assigning a name to an element of a specified type or of renaming an object.

The FORMAT @ statement lets the toolmaker derive the syntax of a new language from the syntax of its reference language. Productions may be modified and given additional semantic meaning with the FORMAT @ statement, but not without limit. A system of rights on productions establishes the limits. The @ on keyword FORMAT @ prevents users

from including such statements in their operation definition segments. Toolmakers however, can use FORMAT @ statements to extend their grammars to recognize invocations of the new operation and extend the semantics of existing productions when the new operator on a new type closely parallels operations on older types.

Finally, the ASSERT statement allows toolmakers and users to specify predicates and other Boolean relations between inputs and outputs of operations or descriptions that they expect to be true.

Full descriptions of Conlan, including concepts and constructs, primitive set Conlan, and base Conlan are given in R. Piloty et al., "Lecture Notes in Computer Science," *Conlan Report* (Springer-Verlag, 1983).

J.F. Blackburn

ELECTRONICS

THOMPSON-CSF AGGRESSIVELY PURSUES III-V SEMICONDUCTOR R&D

Thompson-CSF, the French electronics firm, is now larger than its parent company, Thompson-Brandt. Brandt has 40,000 employees, but CSF has 130,000. With over 500 people engaged in research, most at the Corbeville facility in suburban Paris, Thompson-CSF will be highly competitive in the international electronics marketplace.

Ten percent of the research staff is engaged in III-V semiconductor device research under the direction of Dr. N.T. Linh, while a nearly equal number are doing III-V crystal growth and optics research and report to J.P. Duchamin. From the two groups, Thompson-CSF recently formed a GaAs integrated circuit (IC) development and production team with 50 members. Twenty-five deal with technology, 12 with linear microwave work, and 12 with logic; there is also a director. This development team, which uses only GaAs material, is expected to expand soon to 80 employees.

The team members are now 18 months into a 5-year program. During the second 18-month period, they expect to consolidate their technology for the final development and production phases to follow. Presently, they have 10,000 sq ft of clean room facilities and use 1.0-μm lithographic standards for ion implantation into 2-in.-diameter nonchrome substrates. Activation of the implanted silicon dopant is unconventional; sputtered-on Si_3N_4 encapsulant is used to carry out impurity activation at 850 to 900°C for only 2 minutes. The approach not only precludes unwanted impurity diffusion, but it is much less demanding of the encapsulant. Another unconventional process uses AuGe:Pt for ohmic contacts instead of AuGe:Ni alloys, which are used most often. Device-device isolation is accomplished by implantation of boron ions. Even though the research group has achieved rather impressive results with InP metal-insulator-semiconductor field effect transistors (MISFETs), the development team does not expect to integrate InP devices into their current 5-year program. Reliability appears to be the major factor in the decision. For microwave power, the technology team is enthusiastic about the prospects for a GaAs device based on a semi-insulating Si_xN_y control gate insulator. Operating characteristics appear similar to those of a somewhat similar device developed a few years ago by Texas Instruments for ONR.

High Speed Logic Research

The research group is quite active in GaAs high speed logic design, and interest in this area is expected to increase as the former leader of the logic research group, Nuzillat, has recently been appointed overall Director of Research for Thompson-CSF. Although the logic group has investigated devices with lithographic resolution as small as 0.3 μm, most of the logic device research uses 0.8-μm lithography. A significant part of the work is directed toward frequency synthesizers. A fixed frequency divider (prescaler) usable up to 10 GHz employs master-slave flip flops in a buffered FET logic (BFL) configuration and exhibits 5 pJ/gate. Other devices using the same BFL include a programmable divider operating to 5 GHz, a 4-bit adder, and a 4-bit sequencer. The devices exhibit a typical gate pinch-off potential of from -2.5 to -1.5 V. Using a modified BFL configuration characterized by recessed gates and 30- to 50-second rapid thermal anneal (RTA) activation processing, the speed power product performance figures have dropped from 5 to 0.3 pJ/gate; gate pinchoff potentials have commensurately dropped to -0.9 to -0.6 V.

High-speed random access memory (RAM) research is also under way. An 8-bit-wide RAM of 8 bytes capacity uses normally-off FETs with resistive loads. It features 500-ps access time, 80 mW/byte dissipation, and requires

5,900 mm² area. A new version with nonlinear active loads also features a 500-ps access time, consumes 30% less power, and requires but half the area. A 32-byte RAM using the same nonlinear loads and 0.8-μm lithography is being processed.

Currently under design is a 1,024×1 static RAM using normally-off FETs; it is expected to have a 1.1-ns access time and dissipate 850 mW. Also under design is a 4-bit ripple adder with carry, which will use modified BFL normally-on FETs. It is designed for a fan-in of 5 and a fan-out of 3. Performance expected: 1 mW/gate, 380 ps/gate, and total delay of 1.9 ns.

Boolean logic research is being done. Using architecture similar to that of the silicon-based AM2900 microprocessor series, a GaAs analog of the AM2901 4-bit cascadable arithmetic logic unit is being processed. It has 110 gates dissipating 2 to 3 mW/gate. Measured pinch-off potentials are in the -0.8 ±0.1 V range. With an addition time of 1.5 ns, it is 10 times faster than the best of its silicon "parents" and 20 times faster than the average silicon 2901.

A GaAs analog of the silicon AM2909 micro sequencer is being designed. It consists of 100 gates for use as stack, stack pointer, and two registers. Operating on a 250-MHz clock (about five times the very high speed IC standard), it dissipates 2 W. Testing is clever; automated test jigs developed for silicon devices are used for clock speeds up to 10 MHz. The researchers have found that if the power required by the chip exceeds a critical threshold at 10 MHz and if logic operation is also correct at 10 MHz, 90% of the devices will operate at 250 MHz. Dies consuming less than threshold power at 10 MHz are rejected even if they exhibit logically correct operation, because they will not operate at 250 MHz; 250 MHz testing is time-consuming and more expensive.

InP Technology

M. Armand has recently set a record; over 4 W/mm gate periphery output power was obtained from an InP MISFET operating in the accumulation mode. This represents a 30% increase over results previously reported at the European Specialists Workshop on Active Microwave Semiconductor Devices (see *ESN* 37-8:307-10 [1983]). The active layers of the device are grown by vapor phase epitaxy in a five-temperature PCl_3 system tested to 10^{-4} Torr. Even then, background impurities were too high to consider the use of the buffer layer traditionally used in GaAs devices. A 2-degree off-axis orientation was critical to film morphology. To obtain high power output, the device must be operated on a load line near the upper-right-hand corner of the I-V curves; the requirement, unfortunately, ensures near instant burnout if radio frequency gate drive is lost.

III-V Epitaxy

With four molecular beam epitaxy (MBE) reactors and eight organo-metallic vapor phase epitaxy (OMVPE) reactors at one facility, Thompson-CSF probably has the world's greatest concentration of such machines. The reactors are noted for their capability to control epitaxial layer thickness to within a very few atomic layers at growth rates of about 1 μm/hr. The MBE systems are known for their inherent low background impurity levels; the OMVPE systems also can increase growth rates for production purposes, but generally cannot grow films of extremely low background impurity levels. Linh and his colleagues have used MBE systems to fabricate two-dimensional electron gas (2 DEG) transistors using GaAlAs on GaAs. But they have not yet fabricated the InAlAs on GaInAs type, which are thought to exploit better the 2 DEG effect at room temperature.

Some heterojunctions are characterized by an impurity-doped higher-bandgap material epitaxially deposited on a very thin (e.g., <200 angstrom) undoped material of the same bandgap that, in turn, has been epitaxially deposited on an undoped material of a lower bandgap. Such heterojunctions have been used to create an FET of exceptional characteristics. The FET structure has been variously called a high electron mobility transistor (HEMT), a selectively doped heterojunction transistor (SDHT), and a 2 DEG transistor. Most of these high performance devices have been fabricated by MBE, and those of the most-used GaAlAs/GaAs variety fabricated by OMVPE have not performed as well as those made by MBE. S. Hersee and coworkers appear to be well on the way to improving the competitive nature of the OMVPE process. Using an OMVPE reactor operating at 1/3 atmosphere pressure, they were able to obtain 2°K mobilities of 162,000 $cm^2/V \cdot s$, which are quite impressive--although still not so large as those obtained by MBE. Doping in the GaAlAs layer was $8 \times 10^{17}/cm^3$, and the intermediating undoped buffer layer was 200-angstroms thick. The effective source contact and source-gate channel resistance in all HEMT structures is the parameter most responsible for limiting performance.

The InP/GaInAs lattice-matched heterointerface is also capable of HEMT action. M. Razeghi and M. Poisson of Thompson have teamed with a group at l'Ecole Normale Superieure in Paris to investigate such a device. As undoped InP epitaxial layers with very low background carrier concentration are difficult to grow with OMVPE reactors, the undoped intermediating InP layer was eliminated from the device. Even then, 2°K mobilities were in the 51,000 to 60,000 $cm^2/V \cdot s$. With a band gap discontinuity >0.6 eV, a significant number of electrons in the GaInAs layer may have occupied the upper conduction band valleys, where their heavy mass may have had a detrimental effect on overall mobility. If this proves to be true, InP-based devices may have to be eliminated from HEMT technology considerations unless high quality lattice-matched materials of controllable bandgap can be found.

M. Razeghi and colleagues have also been successful in the use of low pressure OMVPE to improve double heterojunction injection lasers emitting at 1.3-μm. With an InP/GaInAsP/InP structure, threshold current densities as low as 430 A/cm^2 have been obtained at room temperature. The figure is lower than that obtained by liquid phase epitaxy techniques now used for production. Indeed, Thompson has just issued a preliminary data sheet on OMVPE-fabricated quantum well lasers. If the double quantum well structure is introduced, the threshold current may be even lower.

M.N. Yoder

TRANSIENT THERMAL PROCESSING OF SEMICONDUCTORS

Laser-Solid Interactions and Transient Thermal Processing of Materials were the topics of a recent meeting in Strasbourg that attracted scientists from around the world. Sponsored by the Council of Europe, various French governmental organizations, and the Materials Research Society, the 3-day meeting primarily dealt with the processing of semiconductor materials and devices. Most discussion concerned the fundamental aspects of the laser-semiconductor interaction. This continues to be a controversial subject; two schools of thought prevail, and the proponents of each have collected *prima facie* evidence to support their case. Other topics of significant interest include the recrystallization kinetics of thin films, photovoltaics, applications to device processing, and the newest area, photochemical effects.

Fundamental Aspects

The controversy continues over the actual physical mechanisms transpiring after a semiconductor surface has been irradiated by a short laser pulse of high intensity. It is indisputable that the laser energy is primarily deposited in the electronic subsystem and, on a proper time scale, a nonequilibrium condition exists. But the unresolved question is whether a structural change takes place while the energy is still primarily within the electron-hole plasma, or whether the structural change awaits transfer of energy to the lattice.

G. Mahler (Stuttgart Univ., Federal Republic of Germany [FRG]) presented a model that included the coupling between the electrons and the phonons. He showed that even without band gap renormalization by lattice temperature gradients, a plasma confinement may occur from thermodiffusion effects, thereby rendering inaccurate all estimates for the persistence time (of the high density plasma) based on isothermal diffusion. Objections to the model primarily concern the use of linear equations to describe what is probably a nonlinear phenomenon.

B. Laurich and A. Foschel (Stuttgart Univ.) have conducted their experiments in a 4°K ambient. Pulsing high purity silicon with a 65-ns frequency double Nd-YAG laser, they found that even during the time of the excitation pulse, the electronic temperature does not exceed the lattice temperature by more than 40°C. Laurich and Foschel also found that the charge carrier density increased proportionally to temperature, reaching a value of $2 \times 10^{19}/cm^3$ at 320°K, but it was only weakly dependent on laser intensity. A consistent evaluation of the experiment was possible only when carrier drift was considered. They found that the volume occupied by electrons was much larger than the optically excited volume, from which they calculated a plasma expansion velocity of 4×10^6 cm/s. Primary analysis was by band-to-band luminescence spectra.

Nonthermal advocate J.A. Van Vechten (IBM, Yorktown, US) reported that his original Raman measurements of transient surface temperatures no higher than 500°C have now been confirmed and extended by von der Linde et al. Van Vechten has further evidence that the

pulsed laser annealing effect is non-thermal and involves instead a phase transition exhibiting little change in atomic density, electron density, or lattice temperature. Analysis was by picosecond-scale reflectivity transients. They found an initial dip in reflectivity resulting from the interaction of an uncondensed plasma in a cold lattice with the real and imaginary parts of the index of refraction, after which the reflectivity rises in a time too short for significant change in atomic density or coordination. Because the reflectivity then remains constant, they concluded that neither atomic nor electron density nor temperature changes during periods of hundreds of nanoseconds.

J. Bok (l'Ecole Normale Supérieuse, France) viewed the action of laser irradiation and the resulting electron-hole pair creation as the breaking of covalent bonds within the crystal lattice. He sees a runaway process wherein the presence of the electron-hole pairs reduces the effective band gap; this, in turn, increases the rate of electron-hole pair generation and bond breaking. A lattice softening results. His model develops both generation and recombination rates for electron hole pairs. The generation rate is $G = W(1-R) / \tau_p \epsilon d$ where $\epsilon = h\nu = 2eV$, $W = 1J/cm^2$, $d = 3$ μm, and R = reflectivity. He finds the generation rate at 1 ps to be $7\times10^{33}/cm^3s$, while at 10 ns it is $7\times10^{29}/cm^3s$. A hydrodynamic model is developed wherein the pressure (forcing function for plasma expansion) depends only on plasma density and not on temperature. He found a plasma density of $7\times10^{21}/cm^3$, the maximum at which there can be no electron hole pair recombination or expansion. At plasma densities exceeding this, a shock wave expands outward at 10^4cm/s. Thus, with very short picosecond pulses, plasma densities never exceed $10^{21}/cm^2$, and the marked decrease of melting temperature is found.

C. Hirlimann (Univ. of Pierre and Marie Curie, France) presented the first information on femtosecond (fs) excitation of silicon. A ring cavity oscillator with two cavities was built. One cavity was a conventional gain cavity and was pumped with a frequency doubled Nd YAG laser. The second cavity was an absorption cavity, which provided controlled duration clipping of the leading edge of the output pulse. The gain cavity controlled the clipping of the trailing edge of the output pulse. Optical pulses as short as 90 fs thus could be obtained. Output wavelengths used were 440 nm, 620 nm, 678 nm, and 1 μm. The threshold for causing silicon to amorphize was found to be 0.1 J/cm^2 at the 1-μm wavelength. As the pulse duration was increased above 90 fs, surface reflectivity began to increase in the 225- to 360-fs region. Above 360 fs, surface reflectivity began to drop, which was interpreted as the beginning of the crystal transition to the melted state.

G. Wartmann et al. (Essen Univ., FRG) presented the first time-resolved Raman spectrum of the silicon Γ_{25} zone center optical phonon. A 10-ns laser heating pulse at 532-nm wavelength was used. Raman data were obtained from both the heating pulse and from a 355-nm weak ultraviolet probe pulse. The latter ensured that only the first 5 nm of the silicon surface were measured. A new single photon recording technique was used to reconstruct the detailed temporal shape of the Raman scattering from very weak signals. Time resolved spectra were recorded by measuring Stokes and anti-Stokes scattering at several positions of the silicon optical phonon frequency (520/cm). Wartmann obtained the following results:

1. At the beginning of the heating cycle the Raman line was centered at 520/cm, as expected for longitudinal optical (LO)-phonon scattering at 300°K.
2. During heating, the Raman spectrum broadened and became asymmetric with a pronounced low frequency tail with spectral maxima remaining at 520/cm.
3. There was no discontinuity of the Raman scattering when the phase transition occurred.
4. The Raman scattering intensity dropped below the detection limit about 5 ns after the occurrence of the phase transition. Wartmann takes the results to indicate that the phonon (lattice) temperature rises no more than 300°C before melting, although inhomogenous heating could occur.

One possible mechanism that could explain the two different findings is that cathodic emission of electrons of high current density may supercool the semiconductor surface.

Recrystallization

A group of investigators from France and Italy have joined to investigate the effects of laser irradiation of GaAs films. Most of the films were 1,000 angstroms thick and were anodically preoxidized to a depth of 100 angstroms. A ruby laser with a 15-ns pulse

was used in the experiments. It was found that to break down the 100 angstrom surface oxide, a threshold of 1 J/cm^2 was required. Amorphous GaAs could be recrystallized with energy densities between 0.5 and 0.8 J/cm^2; energy densities <0.7 J/cm^2 led to Ga-rich surfaces while densities >0.8 J/cm^2 led to As-rich surfaces. For all levels above 0.8 J/cm^2, a loss of both Ga and As was observed. The loss appeared to be independent of both energy and film thickness and was always between 2 to $5\times10^{16}/cm^2$. Nuclear microanalysis and channeling experiments showed that all Ga and As atoms displaced from their crystallographic lattice sites in the GaAs single crystal were actually complexed with oxygen as Ga_2O_3 or As_2O_3. Attempts to impurity dope GaAs by irradiation in SiH_4 were unsuccessful.

Y. Nissim and colleagues at the National Center for Telecommunication Studies (CNET, Bagneux, France) have used an argon laser Raman microprobe with 1.0-μm resolution to observe dynamically the recrystallization of 1,000-angstrom-thick Si layers subjected to 30-ps, 1.06-μm irradiation at energy densities between 1.5 and 2 J/cm^2. The heating beam was 500 μm in diameter. The intensity ratio of the 292/cm longitudinal optical phonon line to the 267/cm transverse optical phonon line was used to determine crystallinity; a large ratio indicated recrystallization, whereas a small ratio was representative of amorphous regions. Intensity variations in the 521/cm crystalline silicon line were also used for crystallinity analysis. Concentric alternating rings with very sharp transitions between crystalline and noncrystalline regions were found. Resolidification velocities of 100 m/s were calculated.

Defects

A. Chantre (CNET, Meylan, France) has conducted nonmelting laser activation of various impurities in silicon. He has gone on to determine what happens when the same processing is applied to nonimplanted virgin silicon. Using deep-level transient spectroscopy and neutron activation analysis, he found that the processing itself induces several deep level traps in the silicon. He has identified them as follows: (1) Fe_i-Bs complex 0.10eV hole, (2) Cr_i-Bs complex 0.28eV hole, (3) Fe_i 0.45 eV hole, (4) Cr_i 0.22 eV donor, P-Vac complex 0.45 eV donor. However, J.C. Muller and colleagues (Centre de Recherches Nucleaires, Strasbourg, France), found that a 400°C thermal anneal before laser annealing and activation generally prevents the deep level traps from appearing.

R.P. Salathé and colleagues (Univ. of Bern, Switzerland) have shown how very stable and highly efficient luminescent defect centers can be introduced by a highly focused 647-nm krypton laser. A layered structure was grown on a GaAs substrate as follows: $Ga_{0.4}Al_{0.6}As$ 3μm, $Ga_{0.78}Al_{0.22}As$ 0.5μm, $Ga_{0.4}Al_{0.6}As$ 3μm. Only the $Ga_{0.78}Al_{0.22}As$ layer absorbed the 647-nm pulse. The luminescent centers were at 1.54 and 1.59 eV. Luminescent intensity is a nonlinear, nonmonotonic function of pump power. The luminescent centers are formed at temperatures under 400°C and appear to be stable up to 800°C.

Applications

J.P. Colinge et al. (CNET) have tested N-channel metal oxide semiconductor (NMOS) transistors fabricated in silicon-on-insulator films. To obtain the single crystalline silicon films, they first deposit amorphous silicon on SiO_2. Si_3N_4 stripes are then deposited on the α Si, leaving 20-μm gaps between the stripes. Laser recrystallization forms large single crystal stripes of Si with grain boundaries beneath the Si_3N_4 stripes. After Si_3N_4 is removed, the field oxide is grown in the underlying region characterized by grain boundaries, while the active devices occupy the single crystal regions. The result is that of single crystalline islands completely embedded in SiO_2. N-channel transistors made in the islands have exhibited a surface mobility of 650 $cm^2/V\cdot s$--the same as that for conventional NMOS devices. Leakage currents are 5 pA/μm and can be eliminated by applying a negative 5-V substrate bias. A seven-stage, 4-μm NMOS ring oscillator demonstrated a 1-ns gate delay. The high mobility of the films is thought to occur from an intrinsic self-gettering effect of the underlying oxide, rather than being of strain-induced origin.

A new and simple approach to the impurity doping of semiconductor layers was presented by L.D. Nielsen (Univ. of Denmark). Phosphorous- and arsenic-doped oxide films were deposited on both [100] and [111] silicon wafers. Spin-on thicknesses between 1,000 and 3,000 angstroms were chosen. Diffusion and

activation was by 10- to 30-second exposure to a 1,600-W xenon arc lamp and resulted in temperatures between 1,000 and 1,200°C. The oxide was later removed in an HF solution; characterization was by Rutherford back scatter, sheet resistivity, and solar cell activity. The As doping was not successful, but P doping on [100] Si could bring the sheet resistivity as low as 6 Ω/□ .

M.S. Foster

MATERIAL SCIENCES

FIBER COMPOSITE MATERIALS IN THE UK: AERE AND IMPERIAL COLLEGE

This is the sixth in a series of articles reporting research on fiber composite materials in the UK. This month, research at the Atomic Energy Research Establishment and Imperial College is featured.

Atomic Energy Research Establishment

The Atomic Energy Research Establishment (AERE) at Harwell has 16 divisions; each is loosely connected with a discipline. The Materials Development Division is mainly concerned with nonmetallic materials. The Polymer and Composite Group of the division is led by Dr. D.H. Bowen and consists of about 30 scientists and supporting staff, with particular emphasis on high performance composites. The research activities of the group receive outside funding from, for instance, automobile industries, the European Aerospace Agency, and British Aerospace. There is a broad spectrum of composite-related activities, ranging from the development of highly stressed automobile components, joining of composites with metals, and composites for alternative energy generating systems, to consulting services for industry. Drs. N.L. Hancox and D.C. Phillips lead the research effort in resin materials, metal matrix composites, ceramic matrix composites, polymer matrix composites, and fracture of composites. The group is also doing research on fabrication of extremely high quality composites with the filament winding technique and on fabrications of carbon fiber.

In the area of damage tolerance of composites, Drs. D.C. Phillips and R.J. Lee have made a systematic study of the effect of severe stress concentrations on the strength of high performance composites. Their aims were to establish the most appropriate strength criterion for engineering design and to determine the effects of microstructural variables on damage tolerance. First, they reviewed the applicability of the existing fracture models and residual strength criteria for laminates containing holes, notches, and cut-offs. They concluded that although the models are physically different, a common result is that they all predict a notched strength that varies with the reciprocal of the square root of the notch length and contains a characteristic parameter that can be suitably adjusted to fit to notched strength data. Phillips and Lee concluded from their study that for highly notch-sensitive laminates the simplest theory, linear elastic fracture mechanics, appears to fit the data well and is as useful as any of the others. For less notch-sensitive materials, no theory appears to have a demonstrable advantage nor general applicability. There is still a need for a predictive theory that can be applied to a range of geometries and test conditions; there appears to be no theory that will accurately fit the data obtained, even for the simple conditions of the experiments.

In an attempt to provide some general guidelines for tough laminates, Phillips and Lee conducted experimental work to examine systematically how composite notched strength is affected by geometrical parameters (notch length, specimen dimension, and notch tip radius) and material parameters (fiber-matrix bond strength, fiber type, ply orientation, and woven and plied reinforcement styles). Their major findings are described below (see Lee and Phillips, 1982).

1. The most important parameter is the fiber-matrix bond strength. If the bond is too strong, the composite fails in a brittle manner, irrespective of lay-up.

2. Fibers with high strength, intermediate modulus, and high failure strain are good candidates for a tough laminate. The following order would be expected for the laminates, beginning with the toughest: E glass, Kevlar 49, high tensile strength carbon, and high modulus carbon. Hybridization can be used to optimize composite toughness.

3. Although the fracture toughness of a laminate does not appear to vary with specimen thickness, it has been shown to depend sensitively on the thickness of individual plies. In general, thick plies delaminate more easily and therefore decrease the interaction of adjacent cracked and uncracked plies, which increases the toughness. However, thicker plies

increase the susceptibility to transverse cracking.

4. While the effects of stacking sequence on the notched strength are not clear, it has been shown that arranging plies to encourage delaminations between shear cracks in 45-degree plies and adjacent load-bearing 0-degree fibers (e.g., $[\pm 45,0,0]_s$) results in a higher notched strength. If, however, the delamination is suppressed (e.g., $[0,\pm 45,0]_s$), then the shear cracks that develop in the 45-degree plies at relatively low stresses have a detrimental effect on the 0-degree fibers, resulting in a relatively brittle behavior with the 0-degree fibers failing in a stepwise fashion along the 45-degree line.

5. Changes in ply orientation affect the notched strength. Although they are relatively weak, $[\pm 45]_s$ lay-ups are notch-insensitive; large damage zones develop across the entire width of the test specimen, resulting in a controlled and noncatastrophic failure. Because of their relative weakness in the longitudinal direction, they are unlikely to be used to resist tensile loads alone, but they could be used as crack arrestment strips in a laminate containing load-bearing fibers.

6. The style of reinforcement (woven and plied) has an important effect on the notched strength. In woven fabric composites, the formation of a damage zone is largely suppressed, and the materials fail in a relatively brittle manner. Lee is examining the fracture toughness behavior of hybrid woven fabric composites.

Phillips and coworkers also have been involved in the study of fiber reinforced glasses and ceramics, which have mechanical properties similar to those of high performance fiber reinforced resins. The materials could be used at intermediate temperatures higher than those attainable with polymeric systems--for example, in gas turbines. The materials are more stable to ionizing radiation than fiber reinforced plastics, so they might be more attractive for nuclear and space applications. These composites also might be less susceptible to hygrothermal effects; their hardness would make them more erosion resistant; their densities are lower than those of metals. In the late sixties and early seventies, much work was done on developing carbon-fiber reinforced glasses and ceramics; there has been a resurgence of interest more recently as fibers with better resistance to oxidation have become available. Glass and ceramic composites have been developed to extend the temperature range of composites above that achievable with thermosetting resins (around 350°C), and to achieve a truly high-temperature tough system usable above 1,000°C (Phillips, "Fiber").

Almost all ceramic fabrication techniques have been used to manufacture fiber-reinforced ceramics, but the most successful route is remarkably similar to that for resin matrix laminates. Preimpregnated sheets of glass and glass-ceramic composites can be consolidated by a hot-pressing procedure carried out at ~1,200°C and 6.3 MPa. Low thermal expansion borosilicate glass and lithium alumino-silicate glass-ceramics have been used more successfully in minimizing the thermal mismatch strains between fibers and the matrix. The tensile strength of carbon-fiber reinforced glasses and glass-ceramics approaches the rule of mixtures prediction if matrix porosity is kept low; values above 1,000 MPa have been achieved. The shear strengths and toughness depend on the bonding between fiber and matrix, which is believed to be almost entirely mechanical. Fracture energy values (G_{IC}) up to around 20 kJm^{-2} have been obtained. The improved toughness of ceramics is a result primarily of the work done against fiber pull-out. Multiple matrix cracking often occurs due to a combination of thermal mismatch stress and a failure strain of glasses and glass-ceramics that is significantly lower than that of high performance fibers.

Dr. Hancox has been concerned with the development of fiber reinforced elastomers, which exhibit high tensile strength coupled with large transverse and shear strain capability. Such composites are used in the manufacture of hoop-wound flywheels, in simple couplings requiring low torsional stiffness and high flexural stiffness, in composites with greater damping capacity, and in the fabrication of mooring lines whose stiffness can be adjusted to match the sea state.

Fiber reinforced elastomers can be manufactured in a number of well-established ways. Adding elastomers to thermosetting resins also can improve the properties of composites--either by precipitating second phase elastomeric particles, which toughen the matrix by inhibiting the propagation of cracks, or by reacting with the epoxide to produce a homogeneous solid of intermediate properties. Wells and Hancox studied the effects of using urethane rubber-epoxide resin blends as matrices for glass and carbon fibers and for balanced glass fiber cloth composites. As the proportion of urethane elastomer was

increased, the resulting increase in the strain capability of the matrix, coupled with an improved fiber-matrix bonding, produced as much as a 35% increase in torsion failure strain for addition of polyurethane. The transverse properties of unidirectional carbon fiber composites are also significantly enhanced by the presence of 20% urethane in the matrix; apart from a decrease in shear modulus, there are no marked changes in other properties.

R. Davidson and G.M. Wells are examining the other end of the blending range--namely, composites based on a polyurethane matrix with the addition of small quantities of epoxide (~5%). Transverse failure strains ~5% have been achieved with such blending, while the unreinforced matrix material has a strain capability of several hundred percent. Also, the combination of thermoplastic resin and elastomer is being considered.

Other on-going composite research programs in the Polymer and Composite Group include studies of composite-metal bonding, thick adherend shear testing, transverse and torsion testing, carbon fiber manufacture and testing, and metal matrix composites. The composite-metal bonding work, supported by industries, focuses on adhesive bonding for attaching composite components to metal parts. The problems of moisture diffusion, differential thermal expansion, and corrosion are of major concern. A survey of the field of metal matrix composites is being conducted and is supported by industries and British Aerospace.

Imperial College

Fiber composite material research at the Imperial College of the Univ. of London is mainly conducted in the Aeronautics Department. The department has two major areas of emphasis, aerodynamics and structural mechanics. Five of the seven faculty members in structural mechanics are active in composite research.

Prof. F.L. Matthews has extensive experience in a wide range of mechanics problems in composites. He is conducting research in the following areas:

1. The work of jointing in fiber reinforced plastics has been supported by the Polymer Engineering Directorate of the UK's Science and Engineering Research Council (SERC) for a number of years. The emphasis now is on bolted joints.

2. Numerical analysis and modeling are performed for the impact damage of carbon fiber reinforced plastics.

3. Finite element and other numerical methods are used to examine the post-buckling behavior of stiffened panels. The free-edge effects, delamination, and failure process are of primary concern in the study. Analytical and experimental work is done.

4. Work soon will begin on the characterization of stiffness and strength of hybrid composite laminates. Fiber material combinations will include carbon-glass and carbon Kevlar.

Three other projects are supported by the UK's Ministry of Defence (MOD) and the Royal Aircraft Establishment (RAE). Efforts are also being made to develop an interdisciplinary program between aerodynamic and structural mechanics research. For example, what are the interactions between fluid and composite structural components on an aircraft under impact loading? Prof. A. Davis, head of the department, is active in composite research concerning the mechanical behavior of hybrid composites and the behavior of composites under impact loading. Dr. J. Morton conducts research on the notch sensitivity of carbon fiber reinforced plastics. Both woven and nonwoven materials have been used in the study. Another project of Dr. Morton's deals with damage characterization of carbon fiber composites under low velocity impact and the residual fatigue strength of composites after impact. Again, woven materials are used.

The jointing work by Prof. Matthews and coworkers has been extensive. For instance, in the research on bolted joints, over 2,000 tests have been performed to determine the statistical strengths of joints in several forms of glass reinforced plastics. Two review articles written by Prof. Matthews on mechanically fastened joints and adhesively bonded joints provide rather comprehensive reviews of the literature and the state of the art (*Composites*, July 1980 and January 1982).

In a recent article, Matthews (1982) has given some simple guidelines for jointing design. In mechanically fastened joints, the strength depends on material, geometric, and fastener parameters. Thus, it is impossible to quote an "allowable" strength. Lay-ups or material combinations (hybrids) should be used to reduce the stress concentration factor at the hole. The optimum geometry is that corresponding to the situation when bearing, shear-out, and tensile failure modes are equally likely to occur. Maximum strength is obtained when maximum through-thickness restraint is provided;

thus, bolts are better than rivets, which are better than screws. By suitably reinforcing the joint region, one can obtain strength equal to that of the basic laminate, although the use of more than two rows of bolts is not recommended in simple joint configurations (constant thickness, double-lap joints).

Parametric studies have identified the following steps that can reduce stresses within adhesively bonded joints: (1) use identical adherends if possible--if not, equalize the in-lane and bending stiffnesses; (2) use as large an adherend in-plane stiffness as possible; (3) use as large an overlap as possible; and (4) use an adhesive with low tensile and shear elastic moduli. In the article, Matthews also noted that low interlaminar shear and tensile strengths limit joint efficiency. To predict failure load, it is essential to account for the nonlinear behavior of the adhesive. In addition, thermal strain should be included in any analysis.

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T.-W. Chou

METALLURGY AT BBC BROWN BOVERI, BADEN, AND THE SWISS ETH-ZURICH

Two centers for metallurgical research in Switzerland are interested in fracture mechanics. BBC Brown Boveri is working on the strength and fracture mechanics of turbine blades. The Swiss Federal Institute of Technology (ETH-Zurich) is interested in the relationship between the method of producing a material and its fracture mechanics properties, including stress corrosion cracking. Previously, rapid solidification and ion implantation research at BBC Brown Boveri was described by D.E. Polk, *ESN* 35-8:312-314 (1981); melting metallurgy and fracture mechanics activities at ETH-Zurich and alloy processing and mechanical properties studies at BBC Brown Boveri were described by P.A. Clarkin, *ESN* 36-7:157-160 (1982).

Brown Boveri, Baden

The generation, distribution, and use of electricity are the main industrial activities of Brown Boveri. Founded in Baden in 1891, Brown Boveri is now composed of major companies in Switzerland, the Federal Republic of Germany (FRG), France, and North America; there are also companies in 17 other countries. The parent company has its headquarters in Baden, where the Corporate Research Center is located.

In 1980, Brown Boveri claimed to have spent about $450 million on research and development, amounting to 9% of its total business turnover. Almost half of the company's business comes from products that have been on the market less than 5 years. Research and development are also done by the three central laboratories of the national companies in Heidelberg, FRG; Baden-Dättwil, Switzerland; and Le Bourget-Paris, France. In addition, the company divisions of BBC Brown Boveri and Co., Baden; Brown Boveri and Cie, Aktiengesellschaft, Mannheim, FRG; and CEM-Cie Electro-Mécanique, Paris, have their own first-line testing, development, and design departments.

Metallurgy and materials are important to Brown Boveri's activities. For example, the latest company booklet "Research at Brown Boveri" highlights projects such as the use of Recoma® high energy density permanent magnets for variable speed motors (Paris); energy storage in metals with memory capacity (Dättwil); superplastic forming of titanium (Dättwil); solar energy coatings, latent-heat-of-fusion storage paraffins, semiconductors, and filters (Heidelberg); the microstructure-dependent electrical properties of zinc-oxide varistors (Baden); composite ceramic zinc oxide insulator resistors for overvoltage protection (Dättwil); fiber bundle light-activated silicon thyristors for high power (1,000 MW or more) control (Baden); liquid crystal displays, of which Brown Boveri is one of the world's largest suppliers (Dättwil); superionic conductors for fuel cells, storage batteries, electrolysis, sensors, and electro-optical displays (Dättwil); the sodium-sulfur battery for electric vehicles (Heidelberg); zirconium oxide ceramic oxygen-ion conductors for exhaust and pollution monitoring (Heidelberg); and structural materials for turbines or generators, including laser holography for metrology and microstrains (Dättwil), fracture mechanics testing of crack growth (Dättwil),

electron beam welding of turbine blades (Heidelberg), and protective coatings for high temperature corrosion (Heidelberg).

The Corporate Research Center is doing work on the strength and fracture mechanics properties of turbine blade materials. Dr. G. Schröder is head of a group working on the mechanical metallurgy of turbine blades, involving Drs. M.Y. Nazmy, R.F. Singer, and J.E. Allison, a postdoctoral fellow from Carnegie-Mellon Univ., Pittsburgh. Schröder emphasized that his group is not involved in esoteric research on, for example, characterizing the nature of internal dislocation structures to better understand the fundamental properties. Rather, he is seeking the practical benefits of turbine materials evaluation, improvement of properties, and cost saving. Of necessity, the fundamental aspects, which are interesting and overlap to some extent with research results being obtained at Brown Boveri, have to be left to others.

Another consideration was the proprietary need to protect research information because of the very competitive nature of material developments for the turbine-related industries. Nevertheless, Singer has been actively involved in the European Economic Community (EEC) Collaboration on Science and Technology (COST) 501 working committee on gas turbine materials. Singer presented Brown Boveri results on evaluating the high temperature creep properties of Inco mechanically alloyed powder, oxide-dispersion-strengthened superalloy materials at the International Nickel Company (Inco)-sponsored conference Frontiers of High Temperature Materials II (*ESN* 37-7:266-71 [1983]). Singer and Gessinger (1982) reported results on the advanced gas turbine blade material MA6000. Singer said that a major consideration of the new EEC COST 501 effort in planning joint projects involved the extent to which real collaboration occurred and how much of the information would be shared (see *ESN* 37-1:21-24 [1983]). The subject of sharing information was interesting because of the "quid pro quo" always associated with ONR liaison visits and because of a report in "Research at Brown Boveri" by Franz Luterbacher, Chairman of the Board. He mentioned that "research performs the important function of being a *window to the outside scientific world*, through which Brown Boveri is able to keep in close contact with the world-wide community of scientists and enjoy a fruitful exchange of views."

Nazmy has been continuing work with colleagues on cast nickel-base superalloy materials. For alloy IN 738, he has examined the effect on subsequent high temperature (850°C) low cycle fatigue behavior of prior high temperature exposure to air, argon, and sulfur-containing ash environments. In addition, Nazmy has done research on the formation of grain boundary voids after cold working and annealing of IN 738, IN 939, and IN 100 alloys; the effect of room temperature prestrain and subsequent heat treatment on the creep life of IN 738 alloy at 850°C; sequential effect of creep and fatigue at 850°C on the creep or fatigue life of IN 738 alloy; and the effect of multiple cracking on the high temperature low cycle fatigue life of multiply notched IN 738 alloy. The work has covered microstructural observations ranging from transmission electron microscopy--for observing dislocations within $Ni_3Al(\gamma')$ particles and the distribution of carbide particles at the matrix grain boundaries and within the grains--to scanning electron microscopy at lower magnification (for the distribution of γ' particles and the observation of cracks). Recently, Nazmy (1983) reported on the effects of strain rate and strain wave shape on the high temperature, low cycle fatigue life of cast IN 738 material. The results were analyzed by the strain range partitioning method of dividing the total strain range, in this case into four components: completely reversed plasticity, completely reversed creep, tensile creep reversed by compressive plasticity and tensile plasticity reversed by compressive creep. Nazmy and Meixner (1983) reported on an LVDT method of detecting cracking in the low cycle fatigue testing of IN 738 material depending on the diametral asymmetry of displacements measured across the specimen. In a COST 50 study, Nazmy and Wüthrich (1983) have measured the creep crack growth rate in fracture mechanics tests of cast IN 738 and IN 939 at temperatures from 800 to 950°C.

At Brown Boveri, J.E. Allison has extended work on fatigue crack growth rates measured in titanium alloys; his earlier research had been done with A. Gysler of the German Aerospace Research Establishment (DFVLR); G. Lütjering of the Technical Univ., Hamburg-Harburg; and his PhD thesis advisor, J.C. Williams of Carnegie-Mellon (Allison and Williams, 1983). An interesting observation by Atrens, Hoeffelner, Duerig, and Allison (1983) is that subsurface fati- gue crack initiation occurs in zero minimum stress to tension high cycle fatigue tests of Ti-6Al-4V material, leading to lives of 10 million cycles and longer where there is a significant drop in the fatigue limit

stress. The results are being investigated further.

Swiss ETH-Zurich

Prof. M.O. Speidel is Director of the Institute of Metallurgy at ETH-Zurich. Speidel did his PhD with Prof. W. Köster in the early sixties and was at Boeing Aerospace, Washington, and Ohio State Univ. before working at the Corporate Research Center and the Central Laboratory, Baden-Dättwil, of Brown Boveri from 1971 to 1978. His institute is equipped with modern pilot-scale materials production facilities, including electroslag remelting equipment for casting 10-cm-diameter, high-quality steel ingots. Computer-controlled mechanical testing equipment is available for fracture mechanics testing of steel and superalloy materials--particularly for creep testing at high temperatures and for electrochemical monitoring of stress corrosion fracture mechanics testing in various liquid environments. The quantitative method of stress corrosion testing was said to be of considerable interest to the international nuclear reactor community.

Speidel teaches an advanced course on fracture mechanics for students in the Institute of Metallurgy. Diener (1983) published a report on the relationship of the plane strain stress intensity for aluminum alloys and the resistance curve for crack growth. Speidel proposes to make ETH-Zurich a center for determining the effect of metallurgical variables--such as solid solution strengthening, precipitation hardening, and work hardening--on fracture mechanics parameters. Fracture mechanics test results have been verified for disk-shaped specimens (say, 2 cm thick), cut directly from the 10-cm-diameter cylinders produced in the electroslag remelting facility. The idea is to establish as directly as possible the connection between any method of producing a material and the fracture mechanics properties exhibited. Speidel is a member of the European as well as the International Congress on Fracture. Further results are to be reported from ETH-Zurich at the International Conference on Fracture, ICF 6, to be held 4 through 10 December 1984 in New Delhi, India. All indications are that there is a resurgence of interest in the influence of microstructural factors on determining the fracture mechanics properties of materials.

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R.W. Armstrong

MATHEMATICS

MEDIUM-RANGE NUMERICAL WEATHER PREDICTOR

Over the last decade, meteorologists have extended the period for which they can reliably forecast weather worldwide. In the early 1970s, weather predictions were reliable for 1 to 2 days. Now, forecasts for 5 to 6 days are made, and research is focusing on adding a few hours to that time. One of the leaders in the work is the European Centre for Medium-Range Weather Forecasts (ECMWF) in Reading, England.

ECMWF was conceived by the Common Market nations in the late 1960s, was established in 1975, and began regular operational forecasting in 1979. It is financed and staffed by 17 nations: Belgium, Denmark, the Federal Republic of Germany, Spain, France, Greece, Ireland, Italy, Yugoslavia, the Netherlands, Austria, Portugal, Switzerland, Finland, Sweden, Turkey, and the UK. A recent article in *Science* provides general information about the Centre (Kerr, 1983).

The Centre seeks primarily to collect and store meteorological data, to prepare numerical forecasts for medium-length periods and disseminate them to member countries, and to perform research on medium-range numerical weather forecasting. This article addresses the research function.

From the beginning of operations in July 1979 through March 1983, research at ECMWF concentrated on evaluating so-called "spectral methods," which have been used for some time in the United States. ECMWF wanted to judge whether spectral methods could replace the finite-difference approaches that produced numerical solutions to the mathematical model for global weather prediction. As a result of the research, in April the Centre began basing its forecasts on a new computer program that uses spectral methods. According to Dr. D. Burridge, ECMWF's Research Director, that global model appears to meet the standard statistical tests for reliability--essentially a correlation with actual weather variables of at least 60%--for some 12 to 24 hours longer than does the model used at the US National Weather Service's National Meteorological Center (NMC).

The primary reason for the ECMWF's lead over the NMC is computer power: the US NMC's old IBM 360/195 has just been replaced by a CYBER 205 (roughly comparable to ECMWF's Cray 1), but ECMWF expects about an eightfold increase in computer power when its new Cray X-MP arrives later this year. Such a marked advantage in computing power has allowed ECMWF to use, for example, twice as fine a horizontal spatial resolution and 25% more vertical levels than NMC can handle.

Although both ECMWF and NMC use the same general mathematical model and the same spectral methods for numerical solution, ECMWF's code implements two additional variations; these slightly increase the advantage given the ECMWF's predictions by its more powerful computers. The first variation introduces a hybrid vertical coordinate--essentially a combination of the altitude and the ratio of pressure to surface pressure (Simmons and Strüfing, 1983). The coordinate follows the terrain at low levels but is essentially a pressure coordinate at high levels; this reduces numerical instabilities in mountainous regions. The second variation (Wallace, Tibaldi, and Simmons, 1983) models mountains having sharp altitude variations by systematically increasing the altitude of the model mountain above the average height of the actual terrain. Dr. A. Simmons of the Centre's Research Department indicates that the variations extend the duration of the model's reliability in winter months by some 6 to 12 hours.

Much of ECMWF's research for the next 2 years will be directed toward implementing the present model on the soon-to-arrive Cray X-MP computer, and toward troubleshooting as problems arise in the model's performance. In addition, Dr. D. Shaw in the Research Department's data-analysis and acquisition group will lead work on the possible benefit of collecting and analyzing data more often, on new techniques for selecting the most "representative" data to use when much data is available, on quality control of observed data, and on new methods for using data of varying quality. Dr. Simmons' modeling group will explore areas such as the introduction of diurnal radiation variations (to incorporate day/night differences), and the effects of soil-water and snow-depth data on model performance. The numerical experimentation group--headed by Dr. S. Tibaldi--is working with NMC and others to explore the feasibility of using only satellites to collect meteorological measurements for the model. Dr. Tibaldi expects the work to demonstrate the need for new basic science and instrumentation to support remote sensing.

Where might this research lead? Drs. Burridge and Shaw expect that research efforts worldwide over the next decade, combined with increases in available computer power, will lead to reliable forecasts for 10-day periods. Thanks to adequate funding for computers and to strong research efforts, the ECMWF forecasts are likely to remain among the best.

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J.W. Daniel

OCEAN SCIENCES

DYNAMIC PROCESSES IN THE CHEMISTRY OF THE UPPER OCEAN

A NATO Advanced Research Institute, "Dynamic Processes in the Chemistry of the Upper Ocean," was held at Jouy-en-Josas, France, from 6 through 12 July 1983. The first few days were devoted to presentations by each participant; then the institute was divided into working groups to identify key problems and to propose experiments for their solution.

The institute was attended by 26 scientists from Canada, France, the UK, the US, and the Federal Republic of Germany (FRG). The problems in the chemistry of the upper ocean are strongly interdisciplinary, and about half of the scientists were either physical or biological oceanographers; the rest chemists.

Prof. R. Chesselet (Centre National de la Recherche Scientifique [CNRS], France) was the chairman of the organizing committee and acted as host because CNRS provided part of the support for the institute. Dr. J.D. Burton (Univ. of Southampton, UK), the principal organizer of the institute, made the introductory remarks, charging the participants to examine critically the effects of ocean phenomena on chemical processes.

The keynote papers previewed the scope of the problems of the upper ocean. Prof. C.G.H. Rooth (Univ. of Miami, US) stressed the importance of modern data processing, the use of satellites, and the change from two-dimensional to three-dimensional structures for horizontal space scales smaller than 1 to 10 km. Dr. P.S. Liss (Univ. of East Anglia, UK) discussed problems of sampling the sea surface, the importance of biological and photochemical processes there, and the ambiguity of gas transfer measurements in the ocean. Dr. J.H. Steele (Woods Hole Oceanographic Institution, US) discussed space and time scales and demonstrated the unlikelihood that simple linear relationships, such as have been found for vertical profiles, exist between chemical species in horizontal traverses of surface waters. Dr. T. Joyce (Woods Hole Oceanographic Institution, US) discussed the interdisciplinary studies carried out during the Warm Core Rings Project. After the keynote papers, more specialized studies were presented.

Dr. P.G. Brewer (National Science Foundation/Woods Hole Oceanographic Institution, US) discussed: (1) the difficulty of unraveling transport, thermal, and biological effects on the distribution of carbon dioxide, and (2) the use of ^{234}Th in studying particle fluxes. Dr. G. Holloway (Institute of Ocean Sciences, Canada) demonstrated that on the large scale, geostrophic turbulence leads to two-dimensional stirring, but that vorticity and tracers behave differently; thus, caution is needed in using eddy coefficients. Prof. J. McN. Sieburth (Univ. of Rhode Island, US) pointed out that microbial biomass (bacteria and viruses) have largely been neglected and form an important constituent of the upper ocean waters--particularly in the central gyres, where they may oxidize methane.

Dr. O.C. Zafiriou (Woods Hole Oceanographic Institution, US) showed that photochemical reactions in the top boundary layer of the ocean have potentially important influences on gas exchange and the biota, but that much work needs to be done to quantify these processes. Prof. H.C. Broecker (Univ. of Hamburg, FRG) discussed the physical transport mechanisms for gases across the air-water interface. Prof. T.D. Foster (Univ. of California, Santa Cruz, US) discussed convection in the upper ocean and the effects of convection on the boundary layer at the sea surface. Prof. W. Roether (Univ. of Delaware, US) discussed the organic chemical dynamics of the upper ocean and pointed out that the ocean may be a source of formaldehyde and acetaldehyde for the atmosphere.

Prof. R. Chesselet (CNRS, France) reviewed atmospheric inputs to the mixed layer, with particular reference to marine aerosols. Dr. K.W. Bruland (Univ. of California, Santa Cruz, US) discussed the VERTEX sediment trap ^{234}Th data and their use in determining residence times of particulate matter in the mixed layer. Prof. W. Seiler (Max-Planck Institut, Mainz, FRG) reviewed the flux of biogenic gases from the ocean to the atmosphere and showed that for some gases the ocean may be the major source.

Dr. T.R. Osborn (Naval Postgraduate School, US) discussed his measurements of turbulence in the upper ocean using instruments mounted on a submarine. Dr. R.W. Eppley (Scripps Institution of Oceanography, US) reviewed effects of mixing on phytoplankton production and effects of the space and time scales of primary production on sinking of biogenic particles. Dr. J.L. Sarmiento (Princeton Univ., US) presented preliminary results from his model of the carbon dioxide cycle in the ocean.

Dr. J.J. Simpson (Scripps Institution of Oceanography, US) discussed his projects involving the interaction of biological, chemical, and physical processes, primarily in the California Current region. Dr. D. Kamykowski (North Carolina State Univ., US) reviewed the interdisciplinary problems asso- ciated with modeling the ecosystem of the upper ocean. Finally, Dr. T. Joyce (Woods Hole Oceanographic Institution, US) presented some results from the Warm Core Rings project, with particular references to the complex horizontal mixing that takes place around rings.

The working groups made brief reports on the outcome of their deliberations. The reports will be modified to take into account discussion of the reports by the participants meeting as a whole. The working group on gases identified the following key problems in understanding the exchange of gases between the atmosphere and ocean: the absence of agreement between laboratory and field studies and the incomplete knowledge of the role of spray and bubbles. In addition, the group agreed on the need to investigate much more thoroughly the photochemical reactions near the sea surface and to acquire a suitable data base through field measurements.

The working group on particles concluded that the wide range of space and time scales involved in particulate fluxes in the ocean presented a formidable challenge. They pointed out the need to understand small-scale processes involving particles in the ocean surface film and the interaction of particles with microplankton, as well as large-scale stirring processes, which may average sediment trap data differently for particles of different sizes.

The working group on solutes pointed out that most chemical work has stressed vertical variability to the detriment of horizontal and that closely spaced oceanographic stations should be made in order to measure horizontal variations of chemical species. The group also identified the need to understand the interrelations between nutrient transport and primary production on both small and large scales, to understand the processes involved in the correlations found between nutrients and trace substances, to understand how turnover in the mixed layer affects chemical processes, and to determine the rates of dissolution of particles in the upper ocean.

The institute provided an excellent example of how interdisciplinary problems can be tackled. The organizers should be congratulated on their shrewd choice of participants and a format that stimulated useful discussions.

T.D. Foster
Univ. of California, Santa Cruz

NORTH SEA OIL AND THE SCOTTISH COAST

The International Geographical Union Coastal Commission recently met to assess the impact of North Sea oil and gas development on the coast of Scotland. Prof. William Ritchie hosted the field meeting, which began in Aberdeen on 18 July and ended in Inverness on 23 July. During the period, the 25 participants visited all the major pipeline landfalls, the processing and redistribution centers, and the two largest oil rig fabrication sites in Scotland. Ritchie and his colleagues assembled an excellent field guide for the meeting; copies are available from his office (Department of Geography, Univ. of Aberdeen, AB9 2UF).

Exploration for oil and gas in the North Sea began in 1961. The first production licenses were granted in 1964, and oil was discovered in the UK sector in 1969 in the Montrose Field offshore from Scotland. In the UK sector alone, 1,000 wells were drilled from 1967, when the first gas field was brought into production, until 1977. Last year the 2,000th hole was drilled; today there are 20 producing oil and gas fields in the North Sea.

In March, the government decided to reduce oil taxes for new North Sea projects, an action that will have significant impact on UK oil and gas production. This will make the development of smaller, marginal fields more feasible. As a consequence, several oil companies have announced plans to speed up new developments. Shell Oil, for example, plans to develop new North Sea fields in clusters. A conventional fixed platform will be tied to smaller fields within about a 10-km radius. Each of the smaller fields will be developed with small, unmanned satellite platforms.

Development schedules suggest that 17 new oil and gas fields will be brought in over the next few years, and that by the year 2000 there will be 75 producing fields in the North Sea.

What will this accelerated development mean for Scotland and its coast, where most operations are taking place? One thing is clear: the support network

of oil- and gas-related manufacturers and suppliers will be greatly expanded. Government estimates suggest that expenditures for oil-related activities in the North Sea will nearly double by 1986 --from about $5.5 billion spent on offshore support services in 1982 to almost $9.5 billion by 1986.

The price of oil is one major unpredictable factor affecting all offshore oil and gas operations. The UK has responded to recent price cuts by OPEC by lowering its prices; the recently enacted tax changes indicate that the UK is determined to promote and maintain North Sea development. The UK is now a net exporter of oil and gas and clearly expects to remain in this position for the foreseeable future.

Three major oil and gas pipelines landfall on the coast of Scotland (Figure 1). The first pipeline, from the Forties Field, was brought ashore at Cruden Bay in 1973; pipelines bringing natural gas from the Frigg Field reached St. Fergus in 1975, followed in 1976 by a pipeline from the Brent Field. All three pipelines have very long offshore sections, running up to several hundred kilometers from the production fields.

On land, the Forties pipeline goes to a nearby pumping station, from which the crude oil is moved south to the refinery at Grangemouth, near Edinburgh. The gas pipelines at St. Fergus lead a short distance across an area of beaches and dunes and link to the St. Fergus Gas Terminal, operated by British Gas. One terminal consists of the British Gas/Total Oil Marine (UK) Ltd. complex, from which the gas is fed through land pipelines to the UK national gas grid and a northern extension developed by Shell to receive and process gas from the Brent Field.

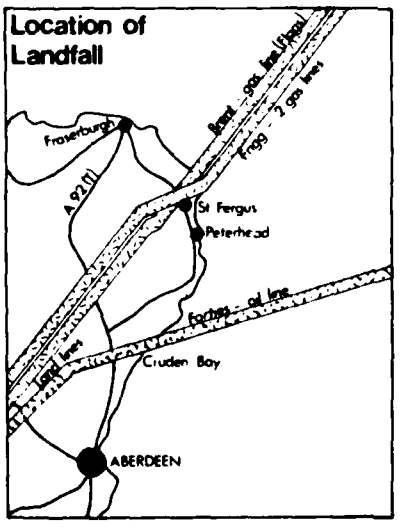

Figure 1. Oil and gas pipelines.

For the three pipeline landfall areas, the engineering technique of pulling the large diameter (about 1 m) coated pipes ashore was essentially the same. A trench was cut through the dunes and beaches and stabilized with sheet piling. A pulling cable attached to a landward winch was fixed to the pipe strings, which were then pulled into the sea from a laybarge. The vessel was anchored a few hundred meters offshore, and once the landfall was made, the barge gradually worked seaward, laying the pipeline toward the production platform. After testing and other related work, the onshore end of the pipeline was connected to a land pipeline going either into the terminal at St. Fergus or southward to Grangemouth from Cruden Bay. At Cruden Bay, the actual pipeline landfall was made directly through the beach and dunes. The dunes are only 3 m high and relatively protected, and the beach is not particularly dynamic. In short, this was a sheltered landfall, and the low sand dune relief provided a simple site for excavation and restoration. In contrast, the St. Fergus area is much more dynamic and exposed. The beaches and dunes are subjected to frequent high waves and storm surge, and the beach is more variable in both plan and profile. In addition, the dune ridge is up to 14 m high and retreating.

For the pipeline landfalls at St. Fergus, the engineering technique was again that of excavating a trench through the dunes so that cables could run from the laybarge to the pulling winch; however, the excavation and sheet piling operations were much more massive than at Cruden Bay.

North Sea oil and gas developments have clearly resulted in significant changes in land use along the Scottish coast. Aberdeen, Peterhead, and Inverness have developed into major service bases for oil exploration and productions, and this has led to changes in the harbors and industrial centers. Sections of the coast of Scotland proved to be ideal for the landfall of the oil and gas pipelines. Development has gone ahead with seemingly minimal damage to the coast. In fact, because of the careful restoration work at Cruden Bay it is now almost impossible to see where the pipeline comes ashore. At St. Fergus, a large gas processing plant has been constructed on the land behind the coastal dune system, but the coastline itself has, in my opinion, suffered only minor impact.

R. Dolan

OPERATIONS RESEARCH

EUROPEAN CONGRESS ON OPERATIONS RESEARCH

The Sixth European Congress on Operations Research (EURO VI) was held at the Vienna Technical Univ. (Austria), 19 through 22 July 1983. About 300 papers were presented to over 500 participants in 33 "streams." The streams with the most papers were Mathematical Programming, Inventory, OR Methodology and Philosophy, Health Care, Microcomputers, Energy (with 11 sessions), and Multiple Criteria Decision Making (with 12 sessions). Sessions were devoted to nearly all of the traditional methods topics in operations research (OR)--for example, graphs, simulation, combinatorial optimization, and fuzzy sets--as well as OR applications areas, such as marketing, traffic, military, and finance.

The opening plenary lecture was given by Prof. Jean Pierre Brans (Univ. of Brussels, Belgium), president of the Association of European Operational Research Societies (EURO). Brans reviewed the activities of EURO, including actions of its 17 working groups, and EUROS' journal, the *European Journal of Operational Research*. He presented three proposals for future EURO consideration: establishing a prize for the best paper presented at the EURO conferences, sponsoring "mini-conferences" on specialized topics within OR, and holding a "summer university" each year to bring together about 20 young European researchers in OR for a summer of interaction. It appeared that most of the audience supported the proposals.

Several papers were concerned with implementation of OR in developing countries. Demetrios Papoulias (Ministry of Agriculture, Greece) presented a paper titled "Operational Research and Socioeconomic Development," in which he examined "whether the form of OR which is used in the developed, capitalistic economies has anything to offer [developing countries]. . . ." (He concluded that "in its traditional form, OR cannot possibly make any sense in these countries.") Papoulias maintains that there is a strong relationship between a country's economic development and the "form of OR" that would be useful in the country. But developing countries have imported OR much as they have imported basic technology, directly from the developed countries. For example, nearly all of the operations researchers in Greece in 1970 had studied abroad, and over half of the members of the Hellenic Operational Research Society now have have postgraduate degrees from abroad. Papoulias says that as a result, the operations researchers in Greece often are not prepared to apply OR to the problems currently facing them. This in turn means that managers and officials think that OR cannot help them. To break this vicious circle, Papoulias suggests that educational programs in OR must be changed to concentrate on methods relevant to the "public administration" sector of each developing country. He proposed a 2-year postgraduate course which concentrates on economic and social applications and methods for students with "a knowledge of mathematics, computing, economics, and the English language." The basic philosophy underlying the course is that operations researchers in developing countries face problems different from those in developed countries, and thus need different OR courses.

In "Present Status of Operational Research," Professors Z. Fijan and B. Beraković (Facultet Strojarstra I Brodozgradnji, Yugoslavia), said that based on studies of OR activities throughout the world, "the interest for OR is decreasing." The spectacular successes of the earliest OR work in the late 1930s have not been duplicated in recent decades, and this has resulted in the "OR Problem" (i.e., decreasing interest in OR around the world). The authors suggest using an OR approach to solve the problem. They envision an international interdisciplinary OR team that would find a solution to the problem. One of the reasons contemporary operations research is in serious trouble, according to the authors, is that OR groups generally are no longer interdisciplinary, as were the earlier, successful groups. An analysis of early (around 1950), mid (around 1966), and recent (1982) publications in the leading OR journals was presented; the authors said it provided evidence of the evolution of OR away from its earliest, most successful form. An example of their analysis, which provides interesting comparisons, is shown in Table 1.

A more optimistic view of the evolution of OR was taken by R.G. Stansfield in his paper, "OR as Genesis." Stansfield believes that OR serves an important function of innovation in new areas of scientific study: "This function, and especially its importance, has largely been overlooked in considering the value of operational research." OR has been creative in causing the growth of new or barely developed fields of science such as econometrics (where studies of productivity and its measurement contributed much), ergonomics, and industrial sociology. Stansfield discussed scientific areas in which OR con-

Table 1

Percentage of Articles in OR Journals in Great Britain (GB) and the US Falling in Three Categories (General--deal with development of OR as an "idea"; cases--deal with solving problems in specific applications; mathematical models--theoretical developments)

	1950		1966		1982	
Category	GB	US	GB	US	GB	US
General	33	28	14	1	13	2
Cases	59	24	36	8	30	8
Math. Models	8	48	50	91	57	90
Total frequency	49	25	28	78	79	40

tributed to development of major ideas. He also noted the importance of the interdisciplinary aspect of OR groups: "Real life obstinately refuses to divide itself into separate, independent pieces neatly corresponding to the scientific disciplines which have grown up within established academic boundaries."

Six sessions were devoted to microcomputers. Papers ranged over topics such as the uses of micros in education and the implementation of OR-related algorithms and techniques on micros. L. Gelders and J. Chuptup (Katholieke Universiteit Leuven, Belgium) presented "Using Micros in OR and IE Education," which described the authors' experiences in introducing microcomputers into their industrial management department. The department's micros are now used in a wide range of education-related tasks, including demonstrations and administrative matters. In addition, students use them to solve problems assigned in courses.

Several papers were devoted to simulation languages and systems that have been developed or adapted for micros. Peter Jennergren (Odense Univ., Denmark) took a different position in his paper, "Simulation in Pascal on Microcomputers." Jennergren believes that users (such as students) should develop simulations suitable for running on micros themselves, rather than using higher level simulation packages. He suggests doing this in Pascal, which he says most technical students in Denmark learn to use. He gave a suggested format for such programming and reported experiences in running simulations on various types of micros. One of the examples concerned a fairly large-scale simulation of icebreaking operations in the Baltic. Brian Hollocks (Business Science Computing, Sheffield, UK) presented the paper, "Exploiting the Micro." He reviewed the ways in which the micro is being used by the central OR group of the British Steel Corporation. Some typical uses include visual interactive simulation modeling, expert systems dealing with fault diagnoses on production plant malfunctions, and planning models for the group and corporate headquarters levels.

An interesting paper in the military applications stream was "Application of Catastrophe Theory to Problems of Military Analysis," by John Dockery and Stefano Chiatti (SHAPE Technical Center, the Netherlands). To model battles involving raids of attacking aircraft against a target area situated behind a missile defense zone, the authors developed an event driven, Monte-Carlo simulation called "COMO III." Dockery and Chiatti noted that military breakthroughs of aircraft into the defense zone are not amenable to analyses with "conventional" models, such as Lanchester models. They also noted that in replications of the simulated battle with continuous changes in input conditions (such as the number and effectiveness of defending missiles and the number of attacking aircraft), quite different results (such as amount of ordinance delivered to the target area) can occur.

Applications of catastrophe theory are characterized by the possibility of observing abrupt and unrecoverable behavior of the dependent variable under smooth changes in the independent variables. An example might be the capsizing of a ship. This behavior is illustrated on surfaces representing catastrophe functions which bear fanciful names such as "cusp," "swallowtail," and "butter-

fly." These particular functions have respectively two, three, and four independent variables. Only the cusp surface has a three-dimensional representation, and it is generally regarded as the simplest type of catastrophe. A graphical interpretation of the cusp catastrophe is shown in Figure 1. The set of points at which the cusp potential function has zero gradient (with respect to the dependent variable), corresponding to stationary states of the system, satisfy a cubic equation having either one or three real solutions, depending on the values of the independent variables. Dockery and Chiatti used least squares methods to fit such a cubic function to data from many simulated battles.

Dockery and Chiatti reported that fitting the cusp cubic to their simulation data has enabled them to identify those variables in their simulation that are relevant to combat breakthroughs. It has led to an understanding of apparent inconsistencies in simulation results in replications or when the independent variables are changed continuously. They are currently extending their surface fitting program to accommodate other types of catastrophes, such as the swallowtail and butterfly. They plan to investigate whether such modeling can lead to a more general representation of command and control phenomena.

The closing plenary lecture was given by Prof. Heiner Müller-Merbach (Univ. Kaiserslautern, Germany), president of the International Federation of Operations Research Societies (IFORS). Müller-Merbach discussed the need for operations research to remain interdisciplinary. He announced that the next IFORS meeting will be held in Washington, DC, from 6 to 10 August 1984. The next EURO meeting is tentatively scheduled to be held in Bologna, Italy, from 17 to 20 June 1985.

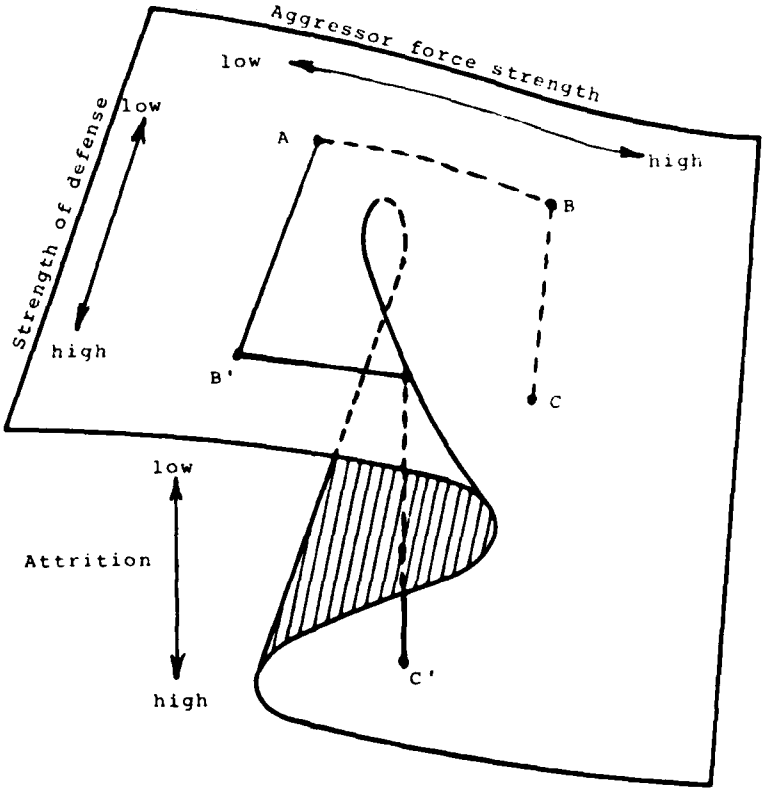

Figure 1. Cusp catastrophe model of attrition of the defense as a function of defense and aggressor force strengths. If the battle starts at combination A and the aggressor builds strength to B, followed by increasing strength by the defense, the attrition level may evolve continuously to the high attrition surface (say point C). On the other hand, if the defense first builds (to point B'), followed by increasing aggressor strength, the attrition level may "catastrophically" change from a low to a high level (point C') as a result of dropping over the "cliff," as shown.

The EURO VI meeting was interesting in a number of respects. First, it demonstrated that in Europe there is a vigorous group of operations researchers who are interested in European problems; they tend to identify themselves with the European region. Second, there is great emphasis on certain areas within OR--multiple criteria decision making, for example. Finally, European operations researchers are rapidly coming up to speed in newer areas, such as uses of microcomputers in OR. There seemed to be more discussion of the philosophy and "ethics" of OR than I would expect to hear at a similar meeting in the US. There also seemed to be proportionately more emphasis on the special problems of operations researchers (and related OR education) in developing countries.

D. E. Barr

PHYSICS

A NEW GAS-PUFF PLASMA SOURCE FOR X-RADIATION

High collimation, precise timing structure, and spectrum control are features that make synchrotron x-radiation ideal for many types of research. Pulsed plasma sources do not have such qualities; but they can be more intense and, unlike gigaelectronvolt-level electron storage rings, are compact and cheap enough for small laboratories. Application areas for plasma x-ray sources include lithography for large-scale integrated electronics, spectroscopy, x-ray lasers and vulnerability studies (see *FSN* 37-3:115-18 [1983]).

A popular way to produce intense soft x-radiation is to inject a "gas puff"--a cylindrical annulus of gas formed by a supersonic nozzle--between the electrodes of a vacuum diode. The gas breaks down when the voltage pulse is applied, and the flow of large currents produces magnetic forces that cause the annular plasma to implode to small radius. At peak compression, the kinetic energy of implosion is converted to internal energy (plasma heating) and radiation. The spectrum of x-rays emitted depends on the type of gas used, its density, and the peak temperature achieved in the compressed plasma pinch.

In the US and France, large water-dielectric transmission line generators are used to drive gas-puff radiation sources with megampere currents on the 100-ns time scale for vulnerability testing (Stallings et al., 1979). On a smaller scale, a capacitively driven system at the Univ. of California, Irvine, produces less intense x-ray pulses with order-of-magnitude smaller currents applied on the 1-μs time scale (Burkhalter et al., 1979). A new capacitively driven gas-puff device has begun operation at the Blackett Laboratory, Imperial College, London, under the supervision of A.E. Dangor of the plasma physics group. He, C.D. Challis, and coworkers from the plasma and spectroscopy groups submitted a report of preliminary experimental results to the 11th European Conference on Controlled Fusion and Plasma Physics held in Julich, West Germany, from 5 through 8 September 1983 (Challis et al., 1983). The experimental and theoretical results and plans for future x-ray laser research are described here.

The gas-puff z-pinch assembly used at Imperial College is shown in Figure 1. A fast-acting valve with a supersonic gas flow nozzle is used to inject a hollow gas shell of radius 2.5 cm and an annular thickness of 0.5 cm between two electrodes separated by 2 cm. The discharge is energized by a 9-μf capacitor bank charged to 25 kV. With a circuit inductance of about 60 nH and a short-circuited diode, a peak discharge current of about 300 kA and a ringing frequency $\Omega = 2\pi f = 1.3$ MHz are achieved. The gas-puff density can be varied by changing the plenum pressure or the discharge time relative to gas injection. Preliminary experiments have been conducted with argon at 5 atmospheres in the plenum. For this mass of gas, the annulus implodes to peak compression within about 1 μs--a time just after peak current.

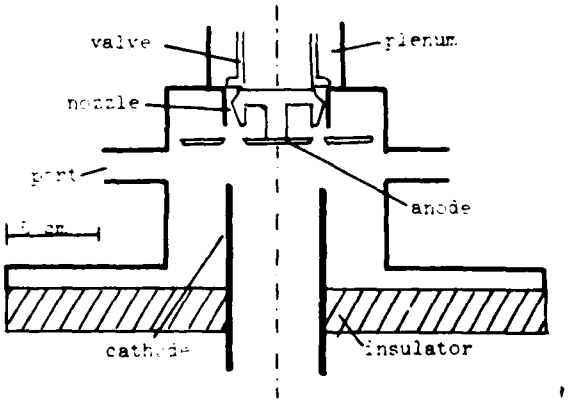

Figure 1. Gas-puff assembly.

The current and x-radiation waveforms are shown in Figure 2. The "notch" in the current following the peak is loading due to the rapidly increasing inductance of the imploding load (rate-of-change of inductance equals resistance). This interpretation is confirmed by visible light streak photography, which indicates a maximum implosion velocity of about 10^7 cm/s. The notch is coincident with strong x-ray emission from the source. Soft x-rays in the 100-eV regime are measured with an aluminum cathode x-ray diode (XRD) and have a duration of about 100 ns. The hard x-rays (1.5 to 20 keV) are monitored with a filtered PIN semiconductor diode. The harder x-rays are emitted briefly at peak compression and temperature. Time integrated pinhole photographs show that x-rays are emitted from a number of millimeter-sized spots strung along the axis of the discharge--a common feature of radiating z-pinches. Pinhole photographs also show very hard (>20 keV) radiation emitted from the anode due to superthermal electrons accelerated by the inductive electric fields.

Figure 3 shows a microdensitometer trace of an argon spectrum obtained with a flat crystal showing He-like resonance and intercombination lines and Li-like satellite lines. The line widths imply a source diameter below 200 μm for this harder radiation component. Emission from lower ionization stages has been observed with a grating spectrometer: Ar IX and Ar X have a source diameter of about 5 mm, Ar XII to XVI a diameter of 0.5 mm.

The simplest way to analyze the dynamics of the plasma source for comparison with experiment is to treat the gas-puff as a thin shell of mass m(g/cm) and length ℓ(cm) imploded by the time-varying axial discharge current I(A). Newton's law for a shell of radius r(cm) at time t(s) is then

$$m \frac{d^2 r}{dt^2} = \frac{10^{-2} I^2}{r} \qquad (1)$$

The current history is derived by solving the circuit equation for discharge of capacitor C through a fixed feed inductance L_f, and varying plasma load inductance

$$L_p = 2 \times 10^{-9} \ell \log(R_w/r),$$

where R_w is the radius of current return at the chamber wall. The circuit equations are then

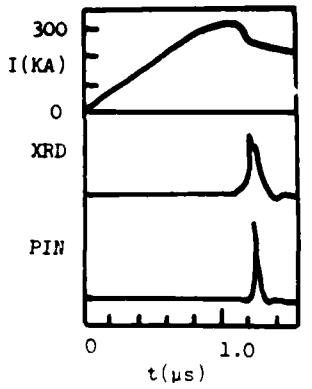

Figure 2. Current and x-ray signals.

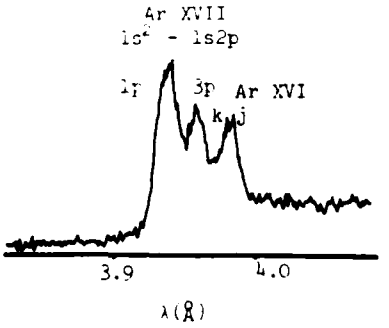

Figure 3. Argon spectrum.

$$\frac{Q}{C} = L_f \frac{dI}{dt} + \frac{d}{dt}(L_p I)$$
$$Q = CV_o - \int I dt \qquad (2)$$

In equation (2), V_o is the charging voltage on the capacitor bank. The equations are solved numerically with initial conditions $r = R_o$ and $I = 0$ at $t = 0$. Integration continues up to the implosion time t_f, at which the radius reaches $R_o/25$, the peak compression observed in experiments.

In practice, equations (1) and (2) are solved to dimensionless form for greatest generality: the current is normalized to I_o, the peak short-circuit current; the radius to R_o; and the time to ω^{-1}. Figure 4 shows the normalized

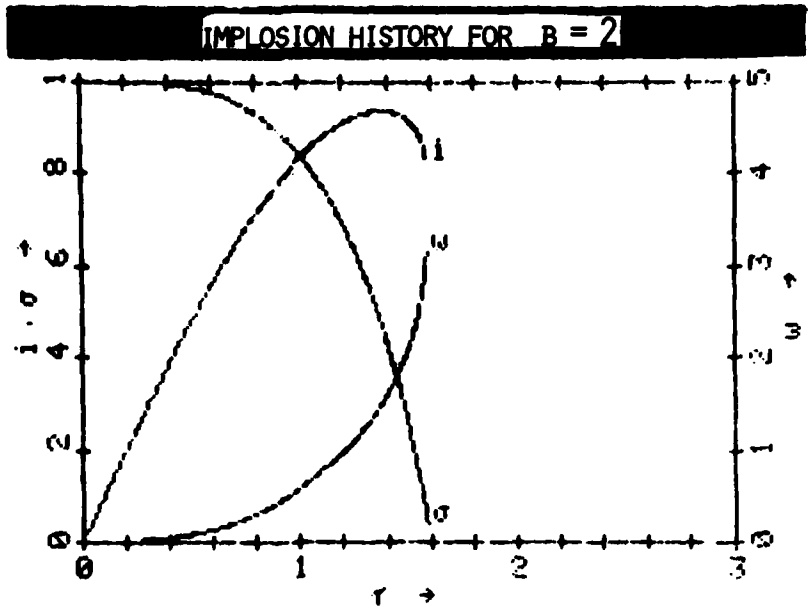

Figure 4. Calculated implosion history.

current i, radius σ, and velocity ω as functions of time for a particular value of implosion mass. These calculated variations can be compared to current traces and streak photographs.

Results of a number of such zero-dimensional calculations for various masses are shown in Figure 5. The quantity β, the free variable that multiplies the dimensionless version of equation (1), is given by

$$\beta = \frac{10^{-2} I_o^2}{m R_o^2 \Omega^2} \qquad (3)$$

The curve labels in Figure 5 have the following definition: $\tau_f = \Omega t_f$, ω is the normalized velocity at time t_f, and ω^2/β determines the efficiency of energy transfer from capacitors to imploding plasma via

$$\text{eff} = (\omega^2/\beta)\,\ell/[L_f + L_p(t=0)]$$

with inductances in nanohenries.

For the experiment, $\tau_f = 1.6$ from the current and x-ray traces so that Figure 5 indicates that $\beta \simeq 2$ and eff≃17%, the maximum value possible for the inductance and load length used. Since $\frac{1}{2}CV_o^2 = 2.8$ kJ, about 500 J is predicted to transfer to the load. With the observed current, $\beta = 2$ also implies that $m \simeq 40$ μg/cm, so that the energy density of the plasma at peak compression is 5 to 6 MJ/g. These mass and energy values are consistent with the implosion velocity observed with visible-light streak photographs.

For the plasma parameters estimated above, both coronal equilibrium and local thermodynamic equilibrium (LTE) models suggest a peak plasma temperature between 50 and 100 eV for 8 to 9 times ionized argon. Preliminary analyses of the He-like spectra indicate higher temperatures. However, the observed emission may be from high temperature regions not characteristic of the bulk plasma, may be produced by instabilities, and are beyond the scope of zero-d modeling.

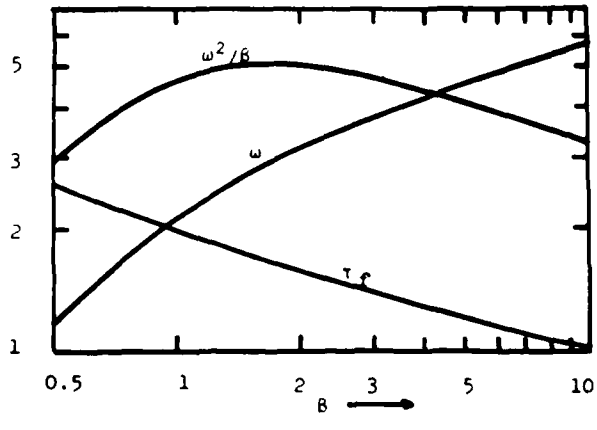

Figure 5. Results of zero-dimensional calculations.

A 1-d Lagrangian magnetohydrodynamic (MHD) code is being developed that will allow more accurate modeling of the collapse phase. For high atomic number gases, ionization is a major sink of electron thermal energy; thus the model must contain reasonable atomic physics. The atomic physics is included by following the ground states of successive ionization stages of the fill gas using published collisional rates. The code includes ion and electron transport with flux limiting. Losses due to continuum radiation and approximate losses due to line radiation are included. The plasma is assumed to be optically thin. Fully implicit differencing is used for the rate equations to ensure positivity and stability without reducing the time step from that required by the MHD. Iteration is employed at two stages: first to solve the rate equations for a given internal energy, and second to obtain a self-consistent solution of the MHD, transport, and state equations.

Dangor has recently been granted funding from the UK Science and Engineering Research Council to develop the gas-puff device for x-ray lasing studies. Plasma radiation pumping for x-ray lasers is attractive because of the high fluences of radiation available (many kilojoules in larger devices). Also, the thin cylinders of plasma formed during implosion are well suited to inversion and gain comparisons along the axis of symmetry and transverse to it. The Imperial College scheme proposes a gas-puff z-pinch with a layered load to produce a pinch with a hot-core of sodium surrounded by cooler neon. It is hoped to invert the n = 2, 3, and 4 levels in Ne IX by resonant photo-pumping using the n = 2 to 1 transition in Na X at 11 angstroms. The wavelengths for stimulated emission in neon transitions are 230, 82, and 58 angstroms, respectively. The difficult part of the technique will be to obtain high gain by generating the proper spatial profiles of temperature, density, and ionization. Much of the planned research is aimed at controlling these parameters. For the present, efforts are being made to improve electrical, plasma dynamic, and radiation diagnostics for a better understanding of single component z-pinches.

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D. Mosher

STATIC CHARGING OF AIRCRAFT BY COLLISIONS WITH ICE PARTICLES

This is the second of two articles on static electrification research at the Univ. of Manchester Institute of Science and Technology. *ESN* 37-7:276-80 (1983) described Prof. Rose-Innes' work on contact electrification of insulators by metals. This article discusses research by Dr. A.J. Illingworth and coworkers on the static electrification of aircraft moving through an icestorm. Interest in charge transfer by collision with ice particles has been renewed because of threats posed by the use of insulating fiber composites and new dielectric materials. Static charging of such components can cause breakdowns at insulator-metal interfaces.

Illingworth's group is in the Physics Department and stresses the physics of the charge transfer process. Laboratory experiments are cheaper than tests conducted aboard aircraft and provide better control and diagnosis of charge transfer phenomena. As with Rose-Innes' work, incorrect models for static charging had to be disproved before more plausible models could be tested.

Early work in precipitation static charging by J.E. Nanevicz indicated that charge separation may be due to the Workman-Reynolds effect. The effect occurs when, after melting by impact pressure, refreezing occurs, and a potential difference appears at the ice-water interface due to selective incorporation or rejection of contaminants into the ice lattice. A potential gradient can also develop by the thermoelectric effect when there are temperature differences; positive and negative charge carriers in the ice have different mobilities and their concentration varies with temperature. A third mechanism proposes that charge exchange is induced by an external electric field. Small, polarized ice crystals hitting a larger metal- or ice-covered target surface remove some of the polarization charge from the target.

Experiments conducted by Illingworth's group suggest that the three mechanisms are not important for charging aircraft. A correct model must explain a charge transfer of 10 to 100 fC per collision with a 100-μm-diameter ice particle. Based on the capacitance of separation, a potential of 50 to 500 mV would be required.

Values of up to 250 V have been reported by the Workman-Reynolds effect using several milliliters of water with 10^{-5} molar concentrations of ammonia freezing in a steady state. To see if the mechanism applies to rapid freezing of small particles, a supercooled water cloud of 20-μm droplets with and without NaCl doping was condensed onto a rotating cylinder. The rotation carried the freezing droplets under a vibrating electrode to detect any developed potential. No transient potentials could be detected for the small particles, though 6-V potentials lasting a few seconds were measured when 3-mm-diameter, rain-sized drops were used. As the impact time with aircraft is measured in milliseconds, and ion separation by the Workman-Reynolds effect takes about a second, it was concluded that the mechanism is not important.

Previous measurements of charge transfer have been deduced from current flow to a target when hit by a cloud of crystals. However, difficulties of measuring ice crystal concentrations are avoided, and the collision and charge transfer dynamics can be more easily observed by studying individual collisions. The apparatus developed by Illingworth for the studies was mounted in a walk-in deep freeze. A loudspeaker cone is pulsed singly or repeated to produce 100-μm droplets. These fall through a freezing section, a free fall section, and into a wind tunnel that accelerates them to 20 m/s. The individual particles then hit 3-mm-diameter targets of various materials and ice coatings which are streamlined so as not to divert impacting particles. A small charge can be embedded in the droplets before freezing. A pair of induction rings in the free-fall section can then sense passage of the particle to determine its terminal velocity, and from it the particle size. Another ring near the target is determines the impact velocity. Charge amplifiers are used to measure the charge transfer as a function of time during the collision. The collision is also viewed with video cameras and tape--the single frame capability is sufficient to view collisions of the slow-moving crystals, and the equipment is much less expensive to use than cinephotography. The collision contact time determined from the charge transfer waveform is about 100 times the 1 μs expected from Young's modulus and elastic scattering theory, and is due to the slightly sticky nature of ice at temperatures above -5°C. Because the contact time is important for charge transfer, Teflon® targets, off which the crystals bounce elastically, have been used to compare with other materials.

A Peltier element was attached to the target to make it 5°C colder or warmer than the ambient air in the deep freeze. It was concluded that temperature gradients do not influence static charging because no change in the sign or magnitude of the transferred charge was observed with changing target temperature. This seems reasonable as thermoelectric potentials should only be a few millivolts.

To test the inductive mechanism, the ice was doped with NaCl to increase its conductivity, and electrodes were placed near the target to permit a variable electric field to be applied. For ice doped to the 10^{-3} molar lever, the transferred charge varied with applied field in a manner consistent with the inductive effect. However, no field dependence was observed at the 10^{-5} molar level expected for atmospheric ice. The charge relaxation time in the lower-conductivity atmospheric ice is much longer than the collision contact time, so polarization charge does not have time to flow across the ice surface.

At the low collision speeds available with the apparatus, contact charging depends on the work function of target material and any ice cover over it. Ice acts as if it has a work function of 4.4 eV. Targets with higher work functions, such as magnesium, tend to charge positively; materials with lower work functions charge negatively. The rotating cylinder technique was used to show that rimed ice (a frost or granular ice coating) below -20°C had a contact potential 500 mV lower than clear ice or rimed ice at a higher temperature. Apparently, the developed potential is related to the degree of disorder in the ice. Since the surface layer of rimed ice has many defects, it is easier for dipoles to align at the surface and change the contact potential. In support of this view, the decay of the potential has a time constant comparable to the recrystallization time. Targets rimed at various temperatures in the single crystal apparatus show a charge transfer that varies from 28 fC at -10°C to -69 fC at -20°C.

When impact occurs at the higher speeds encountered with aircraft moving through ice storms, all materials tend

to charge negatively. The trend indicates that fracturing or cracking may play an important role in charge transfer at high speeds. The single crystal apparatus will be modified so that compressed air can accelerate 100-μm ice crystals to a higher velocity. In the meantime, larger ice samples have been placed on a cooled metal base to crack the ice by thermal expansion. When cracking occurs, potentials up to 40 V were measured across the sample, values much greater than the few-volt contact potentials. It is believed that the propagating crack sweeps out dislocations and picks up the associated charge.

High speed collisions are also studied with a cloud chamber apparatus. The chamber, in a second deep-freeze room, is filled with steam and seeded with a rod that has been dipped in liquid nitrogen to form an ice cloud. To compare different materials at the same velocity or the same material at different velocities, pellets are fired through the cloud from two parallel compressed air guns. The charge picked up during passage through the cloud is measured with induction rings in the lines of fire. The charge increases roughly as velocity for small values--as would be expected from the collision dynamics. At high velocities, a change to negative values occurs because of cracking.

Future work will continue to emphasize charge transfer at the high collision speeds encountered with aircraft. It is important to understand how the phenomenon depends on the crack propagation time in comparison with the collision contact time. Once the mechanism is well understood, aircraft composite material targets will be used for a realistic assessment of precipitation charging.

Illingworth is under contract to construct a new type of distrometer for the US Air Force to measure the size distribution of raindrops. The Air Force plans to use the instruments to determine the degree to which the attenuation of microwave communications depends on the concentration and sizes of individual precipitation elements. Theoretical research in this area is described in *ESN* 37-6:228(1983).

D. Mosher

UNDERWATER ACOUSTICS RESEARCH AT BATH UNIV.

Bath Univ. is one of the leading British institutions in the field of underwater acoustics. Most of the research is done in the School of Physics, which has about 140 undergraduates and 11 graduate students.

Prof. H.O. Berktay, the head, came from Birmingham Univ. about 5 years ago. He is well known in the US, especially for his pioneering work in nonlinear acoustic arrays. The emphasis at Bath clearly is on applied physics. Berktay feels that it would be futile for his school to attempt to be a major player in big science, such as high energy, particle physics, and astronomy. But he is convinced that his group can do significant and highly useful work in a field such as underwater acoustics. The current program at Bath indicates that he is correct. Berktay and his staff recently briefed me on five of their major underwater acoustics projects.

Side-Looking, Towed, Depth-Measuring System

Dr. Roger L. Cloet (Senior Research Fellow and project leader) and Alec J. Duncan (Research Officer) discussed a side-looking, towed, depth-measuring system. Most of the bathymetric charts for the oceans have been constructed from data obtained with single beam normal incidence echo ranging depth sounders. The density of data samples has been extremely sparse. Recently, there has been a growing requirement for fine-detail surveys for civil and naval applications. Multibeam depth sounders to cover a swath of the ocean floor have been developed, and a few are being used. But such systems have two main disadvantages--complexity and cost. During the past two decades, high resolution, side-looking sonars have become popular for mapping ocean floors. The sonars are extremely useful for providing a qualitative picture of the bottom relief but generally are not well suited for making precise measurements of variation in depth. Many researchers have modified the side-looking sonar (which is simple in principle and practice) so as to provide precise information on bottom bathymetry (Chesterman, Tucher, Denbigh et al.). Most techniques have involved the use of some kind of interferometer arrangement in the vertical plane (normal to the track of the sonar system).

The Bath group also uses the interferometer technique with some important innovations. They have developed and fabricated a system and have demonstrated that it can be used to survey an area with a precision which compares favorably with a baseline high-data-density survey made with a conventional depth sounder. In the usual interferometer arrangement, two sets of side-looking transducer arrays,

one above the other in the vertical plane, are mounted on a towed body. One array transmits a pulsed signal, which, after undergoing back-scattering from the sediment, is received by each of two arrays, with a suitable time delay for the top array.

If the array outputs are combined, an interference pattern will result, being constructive when the delay path differences for the two arrays is an integer number of wavelengths. The interferometer information can be used to calculate the grazing angle of the sound pulse with the scattering area. Range to the scatterer is determined by the transit time of the pulse. Thus, one can compute the depth of the scatterer relative to the transducer arrays. The precision of measurement primarily is a function of frequency, pulse length, array configuration, and signal-to-noise ratio.

A major problem with the technique is that if the two arrays are spaced more than a wavelength between phase centers, there will be ambiguity in the angle measurement. For several good reasons, this spacing in practice is likely to be several wavelengths--which is advantageous in terms of precision of angle measurement. The Bath technique essentially eliminates the ambiguity problem by using three arrays, with the spacing between the top and middle and the middle and bottom being different by about one wavelength. The center array transmits, and all three receive. Interference signals from the middle and top are subtracted from those of the middle and bottom to yield a pattern equivalent to a one-wavelength spacing. This provides a coarse measurement, while either or both of the other signals provide the fine measurement of angle. In brief, it is a vernier system.

The Bath equipment operates at 303 kHz, with a pulse length of 200 μs (about 16-cm range resolution) and a horizontal beam width of 1.0 degree. Vertical array spacings are 12 and 13 wavelengths. (These form a high density array as the individual arrays are mounted next to each other.) The design range is about 100 m (about 2-m cross-range maximum). Signals are received from longer ranges, but the depth resolution decreases with increasing range. Phase is sampling every 6 degrees, and range at 16-cm intervals.

The system is installed in a towed body, normally towed at a speed of 5 kn and at an altitude of 20 m above the bottom. Measurements are made relative to the position of the towed body. Therefore, either the body must be very stable, or its motion must be measured and the data used to correct the sonar data. Bath has elected to do the latter and has instrumented the body to measure roll, pitch, yaw, and heave.

All data are recorded on magnetic tape. The signal processing equipment computes the bottom depth, corrected for towed body motion. The data are then plotted as depth contours.

Sea tests have been conducted in Plymouth Harbor using a small craft of opportunity. The results of a survey made with the side-looking system agree well with those obtained with a baseline survey. A Del Norte microwave system was used for navigation control. The Bath sonar survey was made in a small fraction of the time required for the baseline survey (which is the point of the project).

It appears to me that Bath has developed a practical and effective instrument. Basically it is a monopulse system and has the well-known merits and limitations of such systems (Cloet et al., 1982).

Side-Looking Sonar Interferometer

The project described above was supported largely by the Science and Engineering Research Council (SERC), which is equivalent to the National Science Foundation in the US. A spin-off of the work is being supported by the Ministry of Defense (MOD) and is in a very early stage. The aim of the new project is to modify the system concept to detect objects in the ocean volume and measure their altitudes above the bottom. Again, there are both civil and naval applications for such a device. Clearly, a different type of signal processing is required. The bottom mapping system enjoys an advantage in being able to use a fair amount of signal averaging; this will not be possible to the same degree for small object location. The Bath researchers mentioned that they will be measuring phase by quadrative sampling and then will reinsert the signal amplitude. Some of the sonar parameters probably will be changed (e.g., a shorter pulse length). The research schedule calls for collection of data in the Portland area this summer; the information will be used for system development. (The Bath group may expand the system to use multiple horizontal beams.) The project is of real interest to the US Navy.

Penetration of Sound Into Sediments

Dr. Nick G. Pace (Lecturer) and Duncan Wingham (Research Officer) described work on the penetration of sound into sediments; the project is sponsored by MOD.

Propagation paths of sound in the ocean often involve interaction of sound

with the bottom (scattering, reflection, and penetration); for some applications, sound must penetrate the bottom sediment (sub-bottom profiling and detection of buried objects). Thus it is important to understand the mechanism of the penetration of sound into ocean sediments if one is to develop and use relevant equipment in a logical, effective, and efficient manner.

Several years ago, T.G. Muir (Applied Research Laboratories, The Univ. of Texas) measured the penetration of sound from water into water-saturated fine sand for a wide range of grazing angles, from well above to well below the classical plane wave critical angle. (The speed of sound in the sediment was higher than that in the overlying water.) The sound pressure levels at grazing angles below "critical" were significantly higher than initially expected; the results triggered considerable effort by several workers to develop a suitable theoretical model (S. Muir and J. Tjotta, C.W. Horton et al.) but the results have not been completely satisfying. Several theoretical approaches have been considered. It was recognized that Muir's experiments involved several features that differed from the plane wave case: (1) a finite spot was insonified on the bottom; (2) the source was a nonlinear parametric array that was essentially truncated at the water-sediment interface; (3) the secondary wave incident on the interface was spherical; (4) the signal was pulsed (transient); and (5) the sediment was very lossy.

For the past several years, Pace and his coworkers at Bath have been conducting both theoretical and experimental work on the penetration model. They believe that their theoretical model provides insight into the physics of the process and at least gives reasonable qualitative agreement with their experimental data.

They first consider an unterminated parametric array in which the secondary sources are generated by a gaussian-shaped modulated, high frequency carrier (self-demodulation). They assume the carrier (and secondary sources) are collimated with a uniform field in a tube with a cross section the same as the (real) transducer face. They then calculate an impulse response for the array of secondary sources and convolve it with the secondary source modulated wave function to calculate the total secondary wave pressure at a field point in the water. Agreement between theory and experiment is good for the spatial distribution and the received wave shape. Next they terminate the parametric array with a sheet of material that effectively absorbs the carrier and passes the secondary (low frequency) wave. (The sheet is normal to the axis of the parametric array, i.e., normal incidence.) Next, for the terminated array they calculate the impulse function, which is the difference between the unterminated array and the impulse function for the effective aperture at the interface. They convolve the impulse function with the secondary source wave function to arrive at the signal at a field point in the water below the terminating panel. The signal form is as if there is a contribution from the (real) transducer position and from the new (virtual) aperture in the plane of the termination panel. For selected geometries and pulse lengths, the two signals can be resolved; again there is good agreement between theory and experiment.

The case just described is of interest but probably has little practical application. If the parametric array is terminated by a water-sediment interface, it becomes vastly more difficult to derive an analytical expression for the signal at a point in the sediment. The group has not solved the problem, but they have conducted experiments for normal incidence, and the existing theoretical model is very useful in interpreting the spatial variation of the field and the signal shape (see Pace and Ceen, "Time Domain Study").

The next phase of work involved non-normal incidence of a parametric array with a water-sediment interface. The incident angle varied from above to below the classical critical angle. The spatial distribution of the sound field in the sediment has been calculated using numerical methods, and corresponding experiments have been conducted in a laboratory tank with a sediment floor. There is reasonable agreement between calculations and experiment for some geometries and some pulse lengths. Some calculations were made assuming a different profile of secondary sources across the array, with a better match between theory and experiment for some cases but not for others (Pace and Ceen, 1983).

The experimental work is done in a laboratory tank with dimensions of a few meters and with a sediment depth of about 1 m. Primary carrier frequencies are about 1.0 to 1.5 MHz, and pulse lengths (gaussion) are from 4 to 20 μs, and propagation paths range from 10 to 80 cm (depending on geometries). Recent experiments involve changing both the depth of the hydrophone in the sediment and other parameters of the geometry. When the experimental setup was demon-

strated to me, the change in received signal waveforms (amplitude and time history) was very striking as the angle of incidence was changed.

This is good theoretical and experimental work, giving some insight into the process of sound penetration into a sediment.

Acoustic Property of Sheets

This project is conducted by Dr. Victor F. Humphrey (Research Officer) and is primarily sponsored by the Admiralty Marine Technology Establishment (AMTE, Holton Heath). The aim of the project is to develop an instrumentation system for measuring the acoustic properties of materials (absorption, reflection, and transmission coefficients) over a fairly wide frequency range. In principle, the system is quite simple. A collimated sound beam is incident on a flat panel of material to be measured, and the reflected and transmitted signals are measured as the panel is rotated about a vertical axis through the plane of the panel. The Bath system uses a nonlinear parametric sound source--primarily in order to obtain low frequency beams in a small space so that relatively small samples can be used, and because such an array can be operated over a very wide range of frequencies using a single transducer. A low pass acoustic filter (panel) is inserted across the beam to terminate the high frequency carriers before they reach the panel. (Interaction of the carriers with the panel could make it difficult to interpret the data.)

The panels are about 0.5 m on edge. The frequency range is from 5 to 100 kHz. The carrier is around 920 kHz. Both difference frequency and self-demodulation techniques are used. Measurements can be made at spot frequencies or with an impulse source and spectrum analyzer (FFT). The water tank is 1.2×1.2×1.8 m.

The Bath task was to develop the measurement system and measurement techniques. AMTE has now duplicated the system and will use it to make acoustical measurements on special materials of interest. Bath will retain its system and continue to study various materials. Acoustical measurements are very sensitive to the basic physical properties of the sample material. If measurements are made over a range of frequencies and for a wide range of incident angles, it is feasible to calculate the elastic properties of the material with considerable precision.

The Bath group has developed a good, practical, useful instrument that demonstrates one more very appropriate use for the nonlinear parametric transmitting array (Humphrey, 1981).

Side Scan and Sub-bottom Profile Work

This work was discussed by Mike Heaton (Senior Research Officer) and Kathy Dyer (Experimental Officer). Over several years, Bath Univ. has developed, built, and used a side-scan bottom mapping sonar and a sub-bottom profiling sonar. They continue to make improvements as they use the equipment for data collection and surveys. The work has had several sponsors and has been done mostly in support of offshore oil work. The two systems are mounted in a fiberglass towed body (dimension on the order of 1.5 m), which is quite heavy and hangs almost below the towing craft in shallow water. A faired tow cable is used. Normally the body is towed at a speed of 6 kn about 20 to 30 m off the bottom. A 30-kHz conventional depth sounder is mounted in the bow of the towed body.

The sub-bottom profiler operates at 12 kHz, and for an array it uses an Edo transducer in combination with an 88-cm-diameter parabolic reflector to give an 8-degree beam (about 3-m spot size at the water-sediment interface). The pulse length is 0.2 ms. On the records I observed, the penetration profiling extended to about 20 m. I thought that the detail of the sediment layering was excellent; the device seems to be well engineered. The data records appear to be superior to those obtained with several commercial systems I have seen. (It also is a more complex system.) The researchers continue to improve the signal processing. Because the equipment is used (at least partially) to collect data for research work, I was surprised that post-detector data are recorded on magnetic tape. I would think that downshifting the received signals and recording them undetected (with known compression) would be superior and more flexible.

Last year the British raised one of Henry VIII's warships, the *Mary Rose*. It was within view of Henry on shore when it sank just off Seaside (Portsmouth) on its maiden voyage. The Bath group made a post-recovery survey of the area with their profiler. The records showing the depression where the ship had rested these past few centuries were interesting to view on tape playback.

At least one US company is showing some interest in the instrument. Berktay wants to build a nonlinear sub-bottom profiler, which should be an appropriate application for the single

beam nonlinear parametric transmitting array.

The side-scan bottom mapping sonar is fairly conventional. It operates at 48 kHz, with pulse lengths of 1.0 or 2.0 ms and a 1.8-degree (horizontal) by 36-degree (vertical) beampattern; nominal range is 550 m . The records I saw looked very clean, but I believe the range normalization could be improved.

Other Work

Several other projects are under way: studies of bottom reverberation for side scan sonar, bottom classification using side scan sonar, and harmonic distortion in nonlinear beams. Some are student projects; however, contract-sponsored projects are not assigned to graduate students nor used for thesis topics.

In brief the underwater acoustics program at Bath Univ. appears to be in good health, with interesting and useful projects and enthusiastic researchers. Several of the projects should be followed carefully by the US Navy.

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C.M. McKinney

SPACE SCIENCE

IMS WORKSHOP ON EUROPEAN OBSERVATIONS

The study and understanding of the earth's space environment (geospace) has increased dramatically in the last 25 years. Solar-terrestrial physics has emerged as a major discipline that deals essentially with the effects of the variable components of solar radiation (particles, fields, and electromagnetic waves) upon geospace, and particularly the earth's magnetic field and atmosphere. Observations and experimentation in solar-terrestrial physics are performed throughout the world and involve space missions, rockets, balloons, and ground-based observatories.

Many processes and events studied in solar-terrestrial physics occur on a global scale and are extremely complex. For example, the so-called geomagnetic storm involves nonlinear variations in the interplanetary medium, large magnetopause motions, enormous changes in the particle populations within the magnetosphere, unusual variations in the polar cap regions of the earth, pronounced auroral activity, various geomagnetic oscillations, significant ionospheric modifications, and other effects. Prompted by developments in the field and the disparate investigations all over the world, a cooperative effort known as the International Magnetospheric Study (IMS) took place from 1976 through 1979. The IMS was guided by a steering committee under the auspices of the Special Committee on Solar-Terrestrial Physics (SCOSTEP) and included participation from more than 50 nations.

The IMS was a unique scientific international effort now frequently used as a successful model in planning other such ventures. Distinctive IMS programs, each involving the participation of many nations, included dedicated space missions; an extended program of ground-based, balloon, aircraft, and rocket observations; the development of a real-time data system with the capability of feedback to adjust or coordinate observations; and many campaigns to obtain simultaneous data from spacecraft and other observational or experimental methods.

Largely because of slippage in the launch dates of the International Sun-Earth Explorers (ISEE) satellites, the IMS got under way slowly and amounted to a vast observational program that assembled a data base on an unprecedented scale. To enhance the scientific yield, the 5-year period from 1980 through 1984 has been designated the Post-IMS Data Analysis Phase. Many national programs were extended into the Post-IMS effort with significant results.

One important European effort has been a series of workshops with the objective of encouraging European scientists to work together on the analysis and interpretation of data

collected during the IMS. The most recent in the series was the Sixth Workshop on IMS Observations in Northern Europe, held from 16 to 20 May 1983 in Windsor, England. Highlights of the workshop are described below. Earlier workshops in the series were held in different European cities between 1977 and 1982. The first, held in 1977 in Finland, emphasized ground-based observations and dealt primarily with auroras and pulsations. Subsequent workshops used the developing IMS data base advantageously to address a variety of problems such as auroras, substorms, parallel electric fields, pulsations, electrical currents, conductivity, and particle injection events.

The Sixth Workshop was endorsed by the British National Committee for Solar-Terrestrial Physics and sponsored by the Mullard Space Science Laboratory (MSSL) of Univ. College London, the organizing committee headed by Dr. G.L. Wrenn (MSSL), and the US Office of Naval Research. The format built upon the success of earlier workshops in the series, and the program was developed from solicited participant proposals. The program consisted of two topical themes developed by review talks, data presentations with associated poster materials, and subgroup work sessions followed by progress reports and summaries to the full assembly. The topical themes were: (1) Reactions of the Ionosphere and Neutral Atmosphere to Magnetospheric Activity, and (2) Pulsations: Correlated Observations from Satellites and the Ground. Each theme was developed with data from a limited number of selected events. About 65 participants attended the Sixth Workshop.

A. Pedersen (The European Space Research and Technology Centre [ESTEC], the Netherlands) reviewed previous workshops in the series and mentioned other important IMS workshops and forthcoming symposia: the Coordinated Data Analysis Workshop (CDAW 6.2) held at the European Space Operations Centre (Darmstadt, Federal Republic of Germany) in September 1982; CDAW 6.3 at NASA-Goddard, in October 1982; major IMS sessions at the XVIII General Assembly of the International Union of Geodesy and Geophysics at Hamburg, in August 1983; and the Symposium on the Achievements of the IMS to be held in conjunction with the XXV Meeting of the Committee on Space Research (COSPAR) in June 1984 (Graz, Austria). In the discussion, Pedersen, D. Southwood (Imperial College, London), and R. Carovillano (ONR London) emphasized the importance of the IMS workshops for developing the ability of the scientific community to work with large and diverse data sets. The learning process is difficult and slow but crucial to obtaining a large picture of the global solar-terrestrial processes that affect geospace.

M. Blanc (Earth and Planetary Environmental Physics Research Center/National Center for Telecommunications Studies [CRPE/CNET], France) reviewed the effects of magnetospheric energy and momentum sources on the ionosphere and neutral atmosphere. Energy from the solar wind drives magnetospheric processes in an elaborate coupling scheme. For example, solar wind energy modifies the auroral zone and the magnetospheric tail. Tail processes modify the ring current and, through particle precipitation, the auroral zone. The ring current suffers losses directly to interplanetary space but internally couples in mutual processes with the auroral zone and ionosphere (including substorm injections) through mechanisms involving Birkeland currents are electric fields. Ionospheric and atmospheric models have been developed to describe operative complex processes and resulting physical modifications but require improved physical inputs (data) from appropriate measurements. Joule heating and ring current energization are particularly important processes. Available satellite and ground-based data have been complemented in an important way by results recently available from the European Incoherent Scatter Radar facility (EISCAT), the SABRE-STARE radar systems, and the Dynamics Explorer (DE) satellites.

Southwood reviewed the fundamental properties of hydromagnetic (HDM) waves, which are intrinsic to the magnetosphere. The HDM description breaks down in portions of the magnetosphere, such as in the geomagnetic tail and in the neutral sheet, but it is generally applicable. HDM effects relate most commonly to wave and instability phenomena. For example, electrostatic ion cyclotron waves and ring current (hot plasma) instabilities at low frequencies are probably HDM effects. In the vicinity of the polar cusps, the Kelvin-Helmholtz instability (the wind over water instability) produces a mixing of plasma from the solar wind, ring current, and boundary layer. Field line resonances are described as an HDM effect, with isolated magnetic flux tubes oscillating and absorbing energy. Pi2 events (i.e., impulsive or irregular pulsations with periods in the range 40 to 150 seconds) are described as HDM transients that occur primarily in the night-side magnetosphere. Pi2 is a

signature of magnetospheric substorm onset. Because the oscillations are observed far from the auroral zone, they have a potential diagnostic use for substorm identification.

The theory of HDM wave modes is highly developed, but the task of sorting out and identifying such modes in the data remains formidable. Difficulties include inhomogeneities in the magnetospheric plasma, inadequate quantitative knowledge of the background geomagnetic field that underlies the HDM wave modes, the effects of plasma boundaries, and the obscuring roles of the ionosphere and atmosphere. The latter difficulties relate particularly to the inability to make unequivocal identification of an HDM wave event simultaneously by satellite and ground-based measurements. Generation and measurement of HDM waves from an active experiment would be a promising method to develop such an identification capability. With regard to HDM wave propagation, the ionosphere is an anisotropic conductor and the atmosphere an insulator. As a result, short wavelengths normally are not seen, and the polarization rotates (the Hughes rotation) at the ground.

D. Orr (Univ. of York, UK) discussed the physical conditions affecting HDM wave signals. HDM wave periods relate to different parts of the magnetosphere because of variations in the background magnetic field and cold plasma density. Terminology is used to distinguish modes empirically according to period--for example, Pc5 (150 to 600 seconds), Pc4 (45 to 150 seconds), and Pc3 (15 to 45 seconds). Because of the characteristics of the background, cold-plasma-density HDM waves are analyzed theoretically into standing modes or resonances in different plasma regimes. The phase change of the wave signal across a resonance is large (near 180 degrees). The simplest modes to describe theoretically apply under conditions of axisymmetry with respect to the geomagnetic field, a condition that strictly never applies, and include the guided poloidal mode (which has compressional effects) and the toroidal mode (which is guided by the field and also relates to flux tubes).

Parameters useful for identification of HDM modes are wave polarization, phase relationships among wave variables, plasma pressure effects, and wave frequency. In the group discussions, it was pointed out that data from a suitable ground-based magnetometer chain could be used to study wave signatures for phase relationships and HDM mode identification. It is widely accepted that Pc5 pulsations are generated by the Kelvin-Helmholz instability and propagate on the day side of the magnetosphere away from the noon meridian. Recent evidence, however, indicates the presence of Pc5s on the night side of the earth. Pc3 oscillations are common everywhere, suggesting they are locally generated. If so, Pc3 correlations between stations in a chain should be small.

In the Fourier Transform Analysis of ISEE-2 data, C. Mier-Jedrzejowicz (Imperial College, London) reported that different periods were obtained at different orbital locations of the satellite. The fundamental mode was not evident in the data, presumably because ISEE was near the geomagnetic equator. An attempt was made to relate the results to ground-based data. Comparisons were difficult because of inadequacies in magnetic field-line mapping, which gave variations up to 10 degrees in longitude or latitude.

D. Alcayde (Space Radiation Research Center [CESR], Toulouse) explained that dates were chosen to use early EISCAT results in the workshop. One day (18 November 1982) was chosen to study gravity waves. D. Orr (Univ. of York, UK) described the choice of pulsation data. Quiet conditions (Kp, the magnetic activity index, from 1+ to 2+) were chosen for plasmapause studies and Pi, Pc3, 4, and 5 pulsations. More active conditions related to a nighttime Pc4 event. Active conditions (Kp from 5- to 5) were for substorm and large amplitube Pc5 studies.

S. Cowley (Imperial College, London) discussed magnetospheric convection and evidence for magnetic reconnection. In the presentation, Cowley emphasized the work of P. Reiff (Rice Univ.), who determined that the electric potential across the magnetosphere was modulated best essentially by the southward component of the interplanetary magnetic field. ISEE data gave supportive evidence for both steady and impulsive (so-called flux transfer events [FTE]) reconnection. Several reconnection and convection models have been suggested from the observational evidence, but more observations are needed to sort out the models. When the interplanetary field is southward, FTE occur over the whole day-side magnetopause. Mapping of FTE to the ionosphere gives the length scale of 200 km. How to map properly from the magnetopause to the ionosphere is, of course, a major question. A breakthrough would be the determination of an ionospheric signature for the reconnection process. C. Green (Institute of Geological Sciences,

Edinburgh) indicated that FTE occurred approximately every 8 minutes.

Pedersen discussed electric field measurements from the GEOS and ISEE satellites. The double probe method of measurement suffers from a "wake" effect that normally, but not always, must be corrected. Electric field magnitude, and hence convection drift rate, is determined quite well but the field direction has large variations of 20 to 30 degrees typically and up to 50 degrees. Beam experients would give a good determination of the field direction. In the comparison of GEOS 2 and the STARE radar data, the use of field line mapping gave good results in some cases and poor results in others.

In the work sessions on HDM waves, discussions emphasized ways to improve the data analysis and general difficulties in the field. Southwood suggested that Doppler effects on frequency, which may be as large as 20% in space, can be removed by phase subtraction using the simultaneous data from two satellites (ISEE-1 and 2). The phase velocity of the wave signal is not well defined near resonance conditions. The purpose of the Doppler correction is to separate the real variations in space of the HDM signal, which is not an infinite wave train, and to allow better interpretation. The procedure may assist in the major task of identifying an event observed in space with ground-based observations.

R. Grad (ESTEC, the Netherlands) led a discussion on wave observations and corresponding theoretical expectations. Polarization measurements of Pc5 waves showed variations in local time understood in terms of the drift mirror instability coupling to the wave. STARE observations of the polarization at the ionosphere agreed with the satellite observations using field line mapping techniques. Balloon observations of x-ray intensities showed micropulsation frequency modulations. This was understood in terms of very low frequency (VLF) waves interacting with the trapped electron population that precipitate and generate x-rays with the same wave modulation. Grad emphasized the dilemma of working with the large data base now available: the larger the number of simultaneous observations taken into account, the less able we are to reach definitive conclusions. Pedersen commented that the wave period would change slowly due to the outward motion of the cold plasma background at night. The shift in period (say, 100 seconds to 80 seconds) would be accounted for by the adiabatic change of wave number in time (dk/dt). An observation difficult to explain is parallel electric and magnetic fields found in the satellite wave data.

Unique identification of events in space and on the ground remains a difficulty. On occasion, it appears that a ground signal is observed earlier than in space. Grad commented that in such cases the ground observation was at most about one-half hour earlier, and this may result from the location in space of the satellite with respect to, say, the injection event. Wave amplitudes on the ground are characteristically very small. Often there is no peak in the signal intensity in space when presumably a resonance is crossed. Southwood commented that the ionospheric signal is expected to be larger than that on the ground. Also, a resonance can be soft and not pronounced in space, yet the Fourier transform method of analysis will always yield unique resonance frequencies. The method of complex demodulation used by several investigators always smoothes out effects.

Several speakers commented on the presence of heavy ions in the magnetosphere. J.F.E. Johnson (Univ. of Southampton, UK) reported that O^+ flows were characteristically seen by the low energy DE plasma detectors during periods of high activity (Kp 5). It was suggested that so-called Pc2 events, which are rare and occur late in a magnetic storm, may be due to O^+, which is then present in large amounts.

P. Rothwell (Univ. of Southampton, UK) pointed out from GEOS observations that substorm breakup marks a change of properties. For example, the density of O^+ ions exceeds that of H^+ after breakup. Lower altitude measurements indicate that the height at which the O^+ density exceeds that of all other heavy ions rises from 200 to 300 km. Above 300 km, ionospheric characteristics tend to bear no relationship to auroral activity. Below 300 km, recombination proceeds rapidly, and ionospheric and auroral activity relate reasonably well. Recommended studies included the timing of velocities, GEOS footprint studies, comparisons of EISCAT and other data sources, and a better determination of the direction of the electric field for which STARE/SABRE data would be helpful.

Several papers dealt with early EISCAT results presenting derived scalar and vector variables and initial comparisons with other data bases. Scalar parameters included electron density, temperature, and composition. Vector quantities, including convection veloci-

ties and the electric field, require simultaneous data from three radar sites. EISCAT latitudinal coverage is from about 60 to 70 degrees. The data from Tromso are quite good, but transmission problems from Kiruna continue to affect data quality. Density determinations are quite reliable. Construction of the ionospheric electric current density from EISCAT determinations of conductivity and electric field are generally consistent with the equivalent current system inferred from the horizontal component of the disturbance magnetic field measured at the earth's surface. Particle heating was found to be essentially in anti-phase with Joule heating and much smaller than the Joule heating effect in peak regions. Short bursts of heating were identified with particle precipitation events. Rothwell and others emphasized the need to calibrate high altitude EISCAT results through detailed comparisons with other more established data sources such as magnetometers, ionosondes, radar measurements, and auroral observations.

H. Rishbeth (Univ. of Southampton, UK) discussed three-dimensional thermospheric modeling taking into account compositional changes during substorms. A large energy flux and significant horizontal spreading of molecular species occur in the night-side auroral oval during active times. EISCAT observations imply that rapid changes in composition occur at auroral altitudes. Questions include the extent to which such changes propagate to lower latitudes and the recovery time.

Workshop discussions identified several ionospheric studies that would be useful. STARE radar data should help validate EISCAT results, particularly in east-west (longitudinal) considerations. Using EISCAT results, the study of Joule heating and particle precipitation effects might help identify a possible source mechanism for atmospheric gravity waves. High frequency Doppler data should be used to search for periodic variations in ion velocity and to identify any horizontal propagation effects. DE-2 data would be useful to improve the overall picture of any event or analysis using many data sets.

R. Pellinen (Finnish Meteorological Institute, Helsinki) identified useful studies to undertake with special data sets. Direct comparison should be made of electric field measurements and flow fields. Magnetic field changes and substorm development should be studied as events using ground-based and satellite data. With the aid of DE and interplanetary magnetic field data, worldwide response and triggering conditions could be studied. Modeling of the westward traveling surge during substorm development would be useful. Particle precipitation at the ionosphere should be related to GEOS particle observations.

It was announced at the meeting that an EISCAT workshop would be held from 5 through 8 September 1983 in Aussois, France. The workshop was to bring together the EISCAT and magnetospheric communities in a unique learning opportunity to exchange information and methods. It is expected that EISCAT data will contribute significantly to determining ionospheric variables and to the understanding of ionospheric dynamics.

E. L. Carovillano

STATISTICS

THE INTERNATIONAL STATISTICAL INSTITUTE

Dozens of societies and institutes around the world are devoted to various aspects of the field of statistics. The International Statistical Institute (ISI) handles many activities that are typical of professional societies, including sponsoring conferences, publishing journals and other materials, and undertaking various projects through appointed committees. But the ISI is unusual because it actually carries out statistical research and other statistical activities.

The ISI is an old scientific association, established in 1885. Its objectives include furthering international cooperation and interaction on statistical matters; one immediate goal is to help make data collected in various countries comparable. It has about 1,200 members from over 120 countries and an annual budget of about $5 million, obtained from grants from intergovernmental organizations, governments, foundations, membership fees, and sales of ISI publications. New members must be elected, following nomination by five current members.

ISI has four sections; unlike the society itself, they are open to all interested persons: the International Association for Regional and Urban Statistics, the Bernoulli Society for Mathematical Statistics and Probability, the International Association of Survey Statisticians, and the International Association for Statistical Computing.

The institute publishes a number of periodicals:

- *Bulletin of the International Statistical Institute*--appears every 2 years with proceedings of the biennial conferences of the ISI;
- *International Statistical Review*--the main journal of the ISI, published three times a year;
- *Statistical Theory and Method Abstracts*--abstracts of articles from nearly all statistical periodicals in the world, published four times a year;
- *Short Book Reviews*--short reviews of recently published books in statistics, published three times a year;
- *International Statistical Information*--the ISI newsletter, published three times a year; and
- Various directories of statistical societies and agencies.

In 1949 the United Nations Economic and Social Council (UNESCO) provided funds for ISI to administer its International Statistical Education Program. The following year, the International Statistical Education Center was established by the ISI in Calcutta, with joint support of the Indian Statistical Institute. Various educational materials have been developed by ISI, including *A Dictionary of Statistical Terms* by M.G. Kendall and W.R. Buckland (the fourth edition was published last year), and *Teaching Statistics in Schools Throughout the World*, edited by V. Barnett, also published last year. The ISI sponsored the First ISI Conference on the Teaching of Statistics (ICOTS), held at the Univ. of Sheffield, UK, in August 1982. The 5-day conference was attended by over 400 participants from 60 countries. The program was extensive and covered a wide range of interests in statistical education and training, including teaching statistics for all age groups in schools and colleges, the training of practitioners in various applied disciplines, the special problems in developing countries, and the difficulties of teaching specific topics. The two-volume proceedings of the first ICOTS have been published recently.

The ISI undertook in 1972 the World Fertility Survey (WFS), the largest social survey every carried out. The work encompasses 42 developing and 20 developed countries, representing about 40 percent of the world's population. The United Nations Fund for Population Activities and the US Agency for International Development are the primary funding agencies for the WFS; substantial support is also provided by the UK Overseas Development Administration. While the headquarters of the ISI is in Voorburg, in the Netherlands near The Hague, the WFS project, with a staff of 30 professionals, is headquartered in London and is directed by Halvor Gille. (Sir Maurice Kendall was director for a time several years ago.)

Problems associated with the size and growth of human populations have been studied for a long time; Malthus's *Essay on Population*, which discussed relationships between population growth and standards of living, was published in 1798. Even so, Grebenick (1981) commented, ". . . it seems a remarkable feature of the intellectual history of the nineteenth and early twentieth centuries that, with minor exceptions, the discussion of population problems occupied only a peripheral place in the writings of economists and sociologists who preferred to regard the sizes and movements of populations and their structures as a datum of their systems, rather than as a variable in need of explanation."

Early statistical work on population growth was mainly concerned with levels of mortality, possibly because mortality was then more important than fertility as a factor in population growth rates. In recent decades, particularly as birth rates declined in Europe and North America, collection of high quality statistical data, useful for analyzing fertility patterns, has become important. The total fertility rate is defined as the birth rate per woman aged 15 to 49; it indicates the average number of children women would have by age 49 if they bore children at the current age-specific rates of fertility. It is clear that the factors and their interactions that determine the total fertility rate in a population are not simple. For industrialized countries, some general patterns have emerged: fertility is lower in towns than in the countryside; lower among women who have jobs outside the home; lower in households in which the head is occupied in nonmanual work; and lower among women with higher educations. Information about fertility in developing countries is also now becoming available, largely as a result of the WFS.

The WFS helps each country develop the capability to carry out statistical sampling of its population. WFS staff members have developed questionnaires and interview techniques, and these are used, with some variations, in the WFS sample. The data collected in each country belong to that country; only coded data and statistical summaries are received by the WFS staff in London. The instrument used to collect informa-

tion is a single-round sample survey. Care is taken to design the national samples in a technically satisfactory manner, so sampling errors can be estimated and the results generalized to the entire populations. Further, attempts are made to standardize the procedure so results from the sampled countries can be compared with one another. In each country, the sampling consists of two stages, a first sample of households is made to identify eligible women who are to be interviewed in the second stage. The second stage sampling is the principal source of information in the survey.

By the end of 1982, almost 350,000 women throughout the world had been interviewed in the WFS. The data collected provide information on women's childbearing behavior and aspirations, and furnishes policy makers with clues regarding programs most likely to influence fertility. Here is a sample of the major findings to date (see Lightbourne et al. (1982) for more details):

- Substantial fertility declines, of at least one child per woman, have occurred in Asia, Latin America, and the Middle East. Even so, the present fertility rates of 4.6 to 6.3 children per woman in these regions are at least double those in developed countries.
- No fertility decline has been found in sub-Saharan African countries, where fertility ranged up to 8 children per woman (in Kenya).
- Nearly half of the married women surveyed in the developing countries said that they wanted no more children.
- Preferred family size in the developing countries ranges from 3.0 children in Turkey to 8.9 in Senegal, with an overall average of 4.7. The levels are far above the averages of 2.2 to 2.5 children per woman needed in these countries to achieve long-run zero population growth.

The WFS is scheduled to end in June 1984. By that time, director Gille reports, all projects will be completed except for Iran, which no longer appears to be cooperating with the survey. As the WFS project approaches completion, there is a shift of emphasis away from survey operations and toward data analysis, archiving of data, dissemination of findings, and assessment of the lessons learned through the survey experience. A final WFS symposium is planned--possibly for 1984 (the 1980 meeting drew 800 attendees). The method of archiving the WFS data hasn't yet been determined, Gille says. The ISI requires written consent from each country before data from that country can be released to researchers for study. According to Gille, much information from the survey has not yet been investigated--e.g., what social factors affect fertility?

As Lightbourne et al. (1982) state, the WFS is an ambitious undertaking that has succeeded beyond the expectations of its founders. Many other international fertility surveys have been terminated without publishing results--victims of bureaucratic inertia, difficult field conditions, erratic coders and computers, political sensitivities, and many other problems. The WFS is extraordinary, not only in its scope and detail, but also in its ability to overcome seemingly insurmountable obstacles to produce high quality published reports. As one indication of the survey's ability to develop solutions to complex statistical problems, its technical manuals and reports are widely used in graduate-level statistics courses.

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References

Grebenik, E., *The World Fertility Survey and its 1980 Conference*, Report of the International Statistical Institute, (Voorburg, the Netherlands, 1981).

Lightbourne, Robert, Jr., Singh Susheela, Cynthia Green, "The World Fertility Survey: Charting Global Childbearing," *Population Bulletin*, Vol 37, No.1 (March 1982).

D.E. Barr

NEWS & NOTES

ONRL STAFF CHANGES

In September we welcomed aboard a new Scientific Director, Dr. J.W.

Daniel, formerly Chairman of the Department of Mathematics at The Univ. of Texas, Austin. His predecessor, Dr. F.A. Richards, returned to the Univ. of Washington, where he is a professor of chemical oceanography. Also joining the staff was Dr. R.E. Snow, a psychologist from Stanford Univ.

In August, Dr. T.C. Rozzell joined the staff as liaison scientist in biological sciences. He came to ONR London from ONR headquarters, Arlington, VA.

VENICE RESCUE SUNK

The engineering project to save Venice from Adriatic storm surges reported in ESN 37-8:312-18 (1983) has been rejected. According to the *Sunday Times* (London, 7 August 1983) Italy's National Auditing Tribunal in Rome killed the plan "because the engineers did not go through the proper channels."

The $600 million project, approved by the government last December, consisted of movable barriers that would have been installed across the Venice Lagoon's three outlets to the Adriatic. The tribunal threw out the plan because the engineering consortium was appointed directly by the authorities and not after the presentation of public tenders or proposals. The authorities, who had hoped that the method would help avoid the endless delays in examining tenders, will now have to wait years before another group of engineers can be appointed and begin work.

More than 10 years have passed since special legislation was passed to save Venice but little has been done, and only a fraction of the $350 million raised by an international loan has been spent.

E. Nolan

IOS TESTS WAVE RECORDERS

The wave research group at the Institute of Oceanographic Sciences (IOS, Taunton, UK) recently field tested six wave gauges to determine their comparative performance characteristics (Crabb et al., 1983). The tower on which the gauges were mounted was in an exposed location on the southern coast of England; for 6 weeks, the data were transmitted to a shore-based station by a radio link. The following instruments were tested:

1. Comex wave staff (on the tower)
2. NBA Ltd., Wavecrest buoy (100 m from the tower)
3. Datawell Waverider buoy (50 m from the tower)
4. EMI infrared laser (looking vertically downward)
5. Simrad up-looking echo sounder (on the seabed)
6. IOS frequency modulated pressure transducer (also on the seabed)

Crabb presents the performance of each gauge in a series of graphs; the percentage of records rejected as invalid is plotted against the sea state parameters H_s and T_2. The "standard data" for intergauge comparisons were obtained from a Waverider because it provided consistent results before and during the tests. All instruments were calibrated under IOS direction, and all the interface, digitizing, and recording equipment was designed or procured by IOS.

The Waverider buoy was a standard 6000 series with a hull diameter of 0.7 m. The Wavecrest buoy is of a recent design intended to improve upon the performance of the Waverider system. The Comex Wave Staff WSZ is a single vertical wire sensor that detects variations in sea surface elevation. The EMI infrared wave height sensor consists of a small (190×290 mm) sensor mounted above the sea surface that "looks" vertically downward. The light pulses (16,000/s) are reflected from the sea surface back to receiving optics. The Simrad HW Wave Height Sensor is an echo sounder working in the inverted mode. It consists of a ceramic device that transmits pulses of 56-μs duration at a rate of 5 Hz. In addition to the transducer, a transceiver unit generates and transmits the acoustic pulses and then receives and derives an analog voltage from the transmit time. The IOS FM Pressure Recorder is similar to most pressor sensors; it has a diaphragm that is deflected by the applied pressure, causing a change in separation distance of the two electrodes of a parallel plate capacitor. The variable capacitance thus produced is used to control the frequency of an oscillator.

The operational reliability of the six instruments ranged from near perfect (Waverider) to troublesome. The IOS report provides a detailed assessment of the performance of each gauge and the manufacturer's comments concerning the test results.

The tests applied to the data considered the following faults:

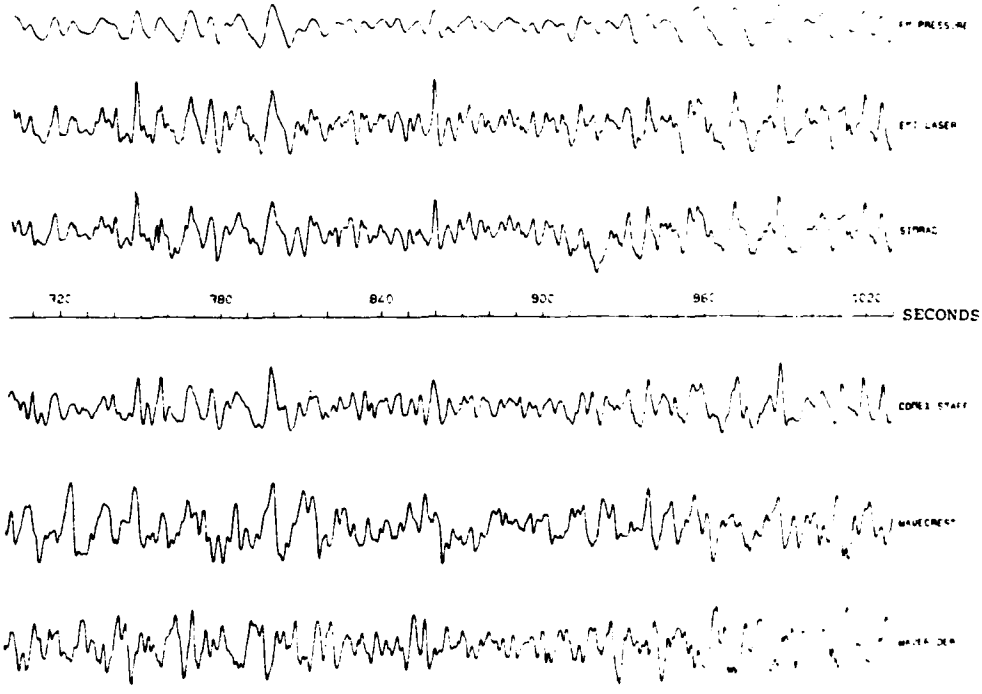

Figure 1. Simultaneous traces of waves from six wave gauges.

1. Ten consecutive data points having equal value.

2. An interval between up-crossings of the record mean level greater than 25 seconds. This is applied only to the Waverider and Wavecrest buoys, and tests for the occurrence of mean line wander.

3. The mean zero crossing period less than the minimum value calculated on a maximum steepness assumption.

4. A difference in the magnitude of successive data points greater than the maximum value expected for the highest wave in the record.

5. Failure of the preceding test on two adjacent data points.

6. Magnitude of data point exceeding four times the standard deviation of the record.

7. Failure of the preceding test on two adjacent data points.

An additional test compared the recorded values of the calibration voltages, which precede and follow each data record.

The results show that in most cases the values of significant wave height and mean zero-crossing period returned by the instruments agree fairly well; however, several instruments (notably the Simrad echo sounder and the Wavecrest buoy) suffered intermittent malfunctions, whereas the Waverider buoy achieved a very high return of valid data. Most of the operational problems of the Wavecrest buoy and the EMI laser apparently were corrected following the field test. Figure 1 is a sample of the traces produced simultaneously by the six instruments.

Reference

Crabb, S.A., J.S. Driver, and R.A. Haine, *An Intercomparison Between Six Wave Recorders at the NMI Tower, Christchurch Bay*, IOS Report No. 154 (Taunton, Somerset, TA1 2DW, 1983).

R. Dolan

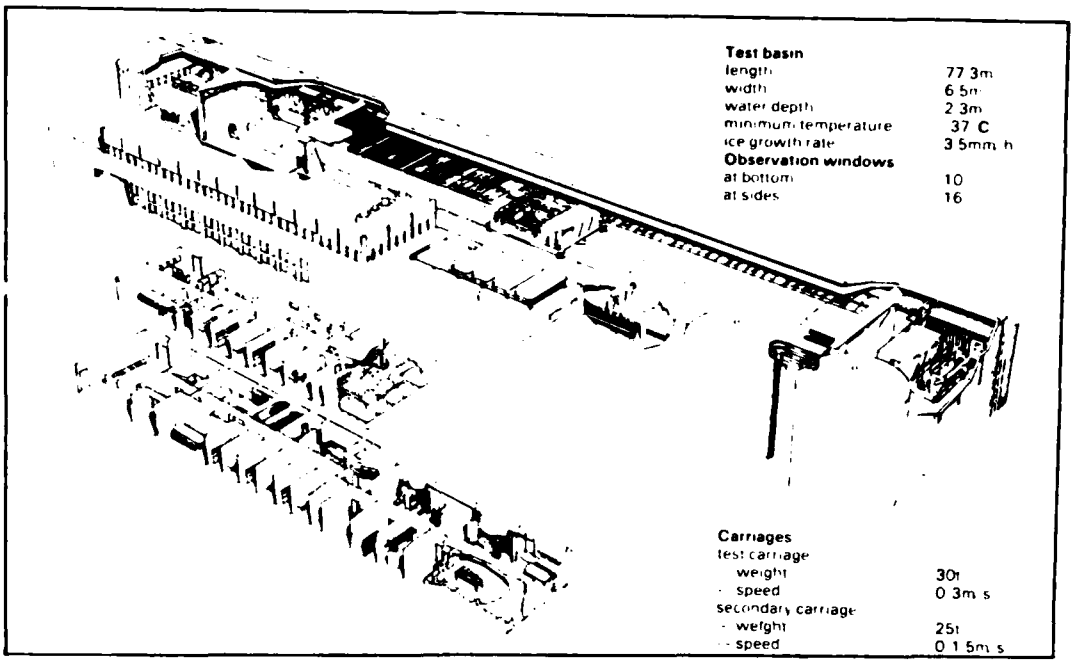

Figure 1. Ice model basin.

NEW ICE MODEL BASIN IN FINLAND

The largest ice model basin in the world is at the new Arctic Research Center belonging to the Finnish shipbuilder Wärtsilä. Opened in February of this year, the center replaces another laboratory that had been in use since 1969. The basin is primarily intended for tests with ships and other marine structures in ice. It can handle models up to 14 m long and 3 m wide. Twin carriages provide flexibility in different kinds of tests, and large external tanks permit all the water to be stored if desired. In addition to the model basin, the center has a special laboratory for research in extremely cold environments. It also contains office space, conference rooms, and workshops.

F.W. Hoeker

COUNCIL OF EUROPE COLLOQUY ON OCEANOGRAPHY--THE SEA TOMORROW

The Colloquy on Oceanography was organized by the Council of Europe and held in Strasbourg, France, from 19 to 22 June 1983. One outcome of the meeting was a suggestion that a European association of sea science and technology laboratories should be established under the auspices of the Parliamentary Assembly of the Council. A group of specialists was appointed to draft a statute to be submitted to a Constituent Assembly of Scientists in November 1983.

The proposal for the association is based on the premise that man's knowledge of the ocean and its resources is inadequate for intelligent exploitation without disturbing the natural balance. The required science and technology exceed the resources of the individual nations. To understand what is necessary to accomplish such aims requires international cooperation in the fields of scientific research and the training of specialists. It was agreed that the countries of the Council have a scientific and technological potential which, properly used, would enable Europe to make an essential contribution to ocean science.

Some of the fields suggested for joint development in Europe were:

- Deep-water research techniques
- The North Atlantic, the South Seas, and the Antarctic
- The coastal fringe
- Exploitation and protection of Mediterranean resources
- The establishment of European workshops to examine the needs of spe-

cialists in oceanography and the elaboration of training programs
- Intensive courses for specialists as part of the Council of Europe's inter-university cooperation program
- Establishment of a network of high-standard pilot centers for the study of highly specialized research problems (a European network of centers of excellence). An example is a proposal to set up a center of excellence for the study of fish diseases at the Univ. of Stirling, UK.

Participants were concerned about how certain ambiguities in the United Nations Convention on the Law of the Sea might affect scientific research and exploitation of marine resources. There was concern that some of the provisions might lead to an outright ban on research in the economic zone of a riverine state.

The colloquy was attended by the 21 member countries of the Council of Europe and seven nonmember countries: Algeria, Canada, German Democratic Republic, USSR, South Africa, the US, and Vietnam.

The colloquy included several round-table discussions and sessions on Biological Oceanography (including fisheries and aquaculture), the UN Convention on the Law of the Sea, Geological Oceanography, Marine Geology, Chemical Oceanography, Physical Oceanography, Mathematical Oceanography/Modelling, and New Technologies.

F.A. Richards

US/UK TEAM SIMULATES FLUID FLOWS

A UK fluid dynamicist and a US numerical analyst are collaborating on several difficult problems in computational/experimental fluid dynamics. Dr. William G. Pritchard and Prof. L. Ridgeway Scott have developed an extensive research program centered at the Fluid Mechanics Research Institute at the Univ. of Essex in Colchester, England.

Pritchard of the Essex Institute is the fluid dynamicist, having been trained and having worked in classical applied mathematics. Scott of the Mathematics Department at the Univ. of Michigan is the numerical analyst, having established a worldwide reputation for his work analyzing finite-element methods for the numerical solution of partial differential equations. They began with a few shared interests during stays at the US Army Mathematics Research Center in Wisconsin and the Institute for Computer Applications in Science and Engineering in Virginia. Now Pritchard and Scott have combined their talents in a program with the following goals: (1) when necessary, to develop and analyze mathematical models of important fluid dynamical phenomena; (2) to develop and analyze computer software to solve the type of problems modeled; (3) to conduct careful physical experiments to gather precise quantitative data on the true phenomena; (4) to compare quantitatively the results of the computer model with those of the real phenomena; and (5) to cycle through these steps until they obtain both a correct model and an accurate numerical procedure for valid simulations.

The program has been quite successful. For example, Bona, Pritchard, and Scott (1981) studied the partial differential equation

$$\eta_t + \eta_x + 3/2\,\eta\eta_x - \mu\eta_{xx} - 1/6\,\eta_{xxt} = 0$$

as a model of the propagation of surface water waves in a channel (x is proportional to the horizontal component along the channel, t to elapsed time, and η to the vertical displacement of the water's surface above equilibrium). They developed and rigorously analyzed a new numerical procedure for the problem, demonstrated that it accurately simulated the true phenomena, and showed the essential need for the dissipative terms in the model in order to obtain accurate simulations.

Using the same overall program, they are working on a number of other difficult problems, such as: (1) bifurcation phenomena, such as the splitting of a bubble in a fluid rotating in a cylinder; (2) the free-boundary flow of a viscous fluid down a ramp with ripples in it; and (3) withdrawal of liquid from a reservoir of stratified fluid. They are also examining the flow of a fluid through a pipe containing a sphere; the precise measurements of drag they hope to obtain are intended to serve as a standard for partially validating many computer codes for simulating fluid flows. A common feature of their work is a rigorous analysis of the real phenomena in a finite rather than an unbounded domain.

Science-policy groups in the US have forcefully recommended increased emphasis on scientific computation and computational science. The Pritchard-Scott collaboration is certainly in this

vein, bringing together an experimentalist and a numerical analyst to attack problems that demand the best talents of both.

Reference

Bona, J.L., W.G. Pritchard, and L.R. Scott, "An Evaluation of a Model Equation for Water Waves," *Philosophical Transactions of the Royal Society, London*, Vol A302 (1981), 457-510.

P.A. Tyler

ORGANIC CONDUCTORS OUT-PERFORM COPPER

Intercalated compounds in which halides and other elements are inserted between the planes of carbon atoms in graphite have been under investigation for nearly a decade. But scientific interest was mostly confined to the two-dimensional conductivity exhibited by such structures. An Israeli team of I. Palchan, D. Davidov, and H. Selig (Hebrew Univ. of Jerusalem) has reported on a new intercalated compound whose electrical conductivity is twice that of an equal weight of copper. Fluorine is used for the intercalation and the carbon-fluorine ratio is greater than two. Although the exact nature of the crystalline structure remains to be determined, the potential of a lightweight, low-cost electrical conductor is significant for both the electronics and the electrical power industries.

W.W. Yoder

PRICES OF ANCILLARY EQUIPMENT MAY SPOIL FRENCH DREAM

The French dream of being the world's leader in communication technology by 1988 has suffered a succession of shattering blows, and the coup d'état may not be far away. The plan to link more than 4 million French homes with two-way optical fiber communications is becoming more expensive than expected. Prices three times those originally calculated are being quoted. The increase is due not so much to the fibers as to the required ancillary equipment. C. Rozmaryn, deputy head of the French telecommunications administration's industrial and international affairs division recently said that "if you take everything into account, the cost differential (between coaxial cable and optical fibers) is not that great." Current estimates are put at about 15,000 French francs per home (i.e., over $2,000).

W.W. Yoder

ONRL COSPONSORED CONFERENCES

ONR London can nominate two registration-free participants in the conferences it supports. Readers who are interested in such participation should contact the Chief Scientist, ONR London, as soon as possible.

International Symposium on Marine Science of the North West Indian Ocean and Adjacent Waters, Alexandria, Egypt, 3-7 September 1983.

Sixth International Conference on Erosion by Liquid and Solid Impact (ELSI VI), Cambridge, UK, 4-8 September 1983.

International Conference on Electronic Properties of Two-Dimensional Systems, Oxford, UK, 5-9 September 1983.

1983 International Conference on Fourier Transform Spectroscopy, Durham, UK, 5-9 September 1983.

Second International Valencia Meeting on Bayesian Statistics, Valencia, Spain, 6-10 September 1983.

Second UK-SMM Workshop, Oxford, UK, 7-9 September 1983.

4th International Symposium on Turbulent Shear Flows, Karlsruhe, FRG, 12-14 September 1983.

Conference on Physical Chemistry of the Solid State: Applications to Metals and Their Compounds, Paris, France, 19-23 September 1983.

15th Europhysics Conferences on Macromolecular Physics, New Developments in the Characterization of Polymers in the Solid State, Hamburg, West Germany, 20-23 September 1983.

Microcircuit Engineering 83 Conference, Cambridge, UK, 26-29 September 1983.

16th European Conference on Laser Interaction With Matter, Imperial College, London, UK, 26-30 September 1983.

ONRL REPORTS

To request reports, check the boxes on the self-addressed mailer and return it to ONRL.

C-10-83: *Fourth Europhysical Conference on Lattice Defects in Ionic Crystals*, by L. Slifkin. This report discusses conference papers that dealt with ionic defects, such as vacancies, solute ions, and dislocations.

C-11-83: *International Meeting on Lithium Batteries*, by J.J. Smith. The conference papers highlighted research results in the electrochemistry of lithium batteries; relatively little emphasis was placed on battery systems. Sessions of the conference addressed the following aspects of lithium battery technology: lithium cyclability, lithium passivation, oxide cathodes, insertion cathodes, solid electrolytes, and polymer electrolytes.

C-12-83: *The European Undersea Biomedical Society Annual Convention*, by CDR A.R. Mananlaysay, USN. The conference dealt with topics ranging from basic physiology to clinical case presentations. In addition to the scientific sessions, the conference included visits to GUSI, the new hyperbaric facility that Dragerwerk AG is building; the West German submarine escape training facility in Neustadt; and the hyperbaric works at Dragerwerk AG in Lubek.

C-14-83: *The 10th International Thermal Spraying Conference*, by H. Herman. In thermal spraying, protective coatings are formed through high velocity melt-spray deposition of a wide range of materials (plastics, metals, ceramics) onto substrates to be protected. The high temperatures for melting are achieved through combustion, with an electric-arc, or within a plasma. The conference examined the scientific bases of the processes, as well as a number of active applications, including corrosion/oxidation and wear and erosion resistant coatings, gas turbine engines, and a number of high temperature applications.

R-7-83: *Applied Psychology in Europe: An ONR Perspective*, by N.A. Bond, Jr. This report is intended to alert American researchers to European developments in applied psychology. The following areas are examined: interactive man-machine interfaces, combat reactions and stress, memory enhancement, large digital simulators, and human performance models.

EUROPEAN VISITORS TO THE US SUPPORTED BY ONR LONDON

Visitor	Affiliation	Organization to be Visited
Dr. J. Campsie	Ocean Study Group Borgergade 34, 2-TA DK - 1300 Copenhagen K	ONR, Arlington, VA NRL, Washington, DC NSWC, White Oak, MD (September/October 1983)

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